MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY

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MEETING OF 1939 DECEMBER 8

Professor H. C. Plummer, President, in the Chair

The President announced the death of Professor R. A. Sampson, and read the following Resolution of Condolence which had been passed by the Council that afternoon, the Meeting standing in silence :—

"The Council desires to record with the deepest regret the loss which the Society has sustained by the death of Ralph Allen Sampson, lately Astronomer Royal for Scotland, and President of the Society from 1915 to 1917.

"His contributions to astronomy touched many fields, and his researches on the motions of Jupiter's satellites are distinguished by their extent, originality and power. By his death, dynamical astronomy has lost one of its outstanding exponents."

The following candidate was proposed for election as a Fellow of the Society, the name of the proposer from personal knowledge being appended :—

John Cassini Lockerbie, Ford Bank, Wetherby, Yorkshire (proposed by W. J. Coombs).

Fifty-four presents were announced as having been received since the last meeting, including :—

H. C. Plummer, Probability and Frequency (presented by the author) ;
H. T. Pledge, Science since 1500 (presented by the Director of the Science Museum) ;
Harold Jeffreys, Theory of Probability (presented by the author).

Miss M. G. Adam and Mr. D. S. Evans were appointed auditors of the Treasurer's accounts for 1939.

THE SCORPIO-CENTAURUS CLUSTER (THE SOUTHERN STREAM)

W. M. Smart, M.A., D.Sc.

1. In the region between galactic longitudes 210° and 330°, and bounded by the parallels of galactic latitude +30° and −30°, a considerable proportion of the B-type stars reveal a community of motion, so far as their proper motions are concerned, suggesting that such stars form a moving cluster; this has been designated the Scorpio-Centaurus Cluster or the Southern Stream. The total annual proper motions, μ, of these stars are mainly in the range 0″·02 to 0″·05, and the great circles along which the stars appear to move are reasonably convergent when one takes into consideration the comparative smallness of the values of μ. If the convergent point of the proper motions can be obtained (on the assumption that all the stars concerned form a true moving cluster) and if the radial velocity of at least one star is known with sufficient accuracy, the kinematical characteristics of the cluster can be obtained; in particular, the parallax and the true radial velocity of each star can be derived.

About a quarter of a century ago Kapteyn made an investigation * on the lines indicated; about the same time Plummer, assuming that the space-motions of the "cluster-stars" are parallel to the galactic equator, obtained results † similar to those of Kapteyn. These earlier researches were handicapped to some extent by the paucity of observational material, notably as regards radial velocities and parallaxes.

Some years later a further comprehensive research on the Southern Stream was undertaken by Rasmuson ‡, followed in more recent times by the investigations of Plaskett (J. S.) and Pearce §, Bertaud ||, and Nisoli and Gérard ¶. The results of these investigations and of the present paper are shown in Table I; in each case the assumption of a moving cluster is implicit. The right ascension and declination of the convergent point are denoted by A and D, the "stream-velocity" in km./sec. by V, and the K term (km./sec.) by K.

TABLE I

	A	D	V	K
	°	°		
Kapteyn	94·6	−42	18·3 ± 0·9	+4·3 ± 0·5
Plummer	96	−39	14·8	...
Rasmuson	99·1 ± 11·5	−45·6 ± 8·2	18·6 ± 2·4	...
Plaskett and Pearce	83·6	−22·9	15·0 ± 1·0	+8·3 ± 0·5
Bertaud	96·8 ± 2·1	−40·3 ± 4·7	...	...
Nisoli and Gérard	86·5 ± 0·9	−27·5 ± 3·8	...	...
Smart	91·2 ± 1·3	−36·8 ± 1·7	18·8 ± 0·4	+5·2 ± 0·7

* *Ap. J.*, **40**, 43, 1914.
† *M.N.*, **73**, 497, 1913.
‡ *Lund Medd.*, Ser. II, No. 26, 1921.
§ *M.N.*, **94**, 679, 1934.
|| *Bull. Astr.*, IX, fasc. x, 1936.
¶ *Bull. de l'Acad. de Belgique*, No. 5, 489, 1937.

The co-ordinates in the last line are for 1950·0; for the remainder of the table the epoch is 1900·0. In all these results the convergent point is within a few degrees of the antapex * of the solar motion.

With the exception of Plummer's investigation, the co-ordinates of the convergent point are obtained from the proper-motion data available at the time, and *it is assumed in all cases that the stars concerned form a moving cluster with a common velocity-vector, V.*

2. The object of this paper is to attempt to resolve the problem: do the stars, which are commonly assigned to the Southern Stream, actually form a moving cluster? The question has recently arisen in connection with Plaskett and Pearce's investigation † on the constants of galactic rotation based on the radial velocities of O- and B-type stars. Having determined the co-ordinates of the convergent point for the stars, 132 in number, of the Southern Stream, as shown in Table I, Plaskett and Pearce then utilise the observed radial velocities of these stars (which are arranged in 8 groups, depending on position on the celestial sphere) to obtain the values of the "stream-velocity," V, and the K term by means of equations of condition of the form

$$V \cos \lambda + K = \bar{\rho}, \qquad (1)$$

in which λ is the angular distance of the mean position of a group from the convergent point and $\bar{\rho}$ is the mean of the observed radial velocities of the stars within the group. The chief feature of their solution is the unexpectedly high value for K, namely, 8·3 km./sec., as compared with the value of 4 to 5 km./sec. obtained in previous radial velocity investigations of the O- and B-type stars. Regarding, in this connection, the kinematical characteristics of the Southern Stream stars as anomalous, Plaskett and Pearce then proceeded to remove from each radial velocity of the "stream" stars an amount varying between 5·9 and 9·6 for the 8 groups, with an average per group of 8·5 km./sec. The effect of this treatment on the analysis of all the O and B stars considered in the general solution for K term and rotational constants was to make the K term virtually disappear, except for a calculable amount due to gravitational effects; in other words, the mystery of the K term—generally found to be of the order of 4 or 5 km./sec. —was regarded as solved, its previous existence being now ascribed by Plaskett and Pearce to the anomalous behaviour of the stars of the Southern Stream.

In a recent paper I ventured to criticise ‡ this part of their work together with their conclusion just mentioned, and, later, Dr. Plaskett has generously acknowledged § the validity of the criticism as to their procedure with the K term. In the paper referred to, I added my own opinion that the stars

* The most recent result for the naked-eye stars, based on the proper motions of the *G.C.*, is (89°, −30°) by Wilson and Raymond, *A.J.*, **47**, 67, 1938.

† *Loc. cit.* and *Publ. D.A.O.*, **5**, No. 4, 1936.

‡ *M.N.*, **96**, 568, 1936. A similar criticism was made independently by Malmquist in *Handbuch der Astrophysik*, VII, 587, 1936; see also a paper by Lall in *M.N.*, **99**, 42, 1938.

§ *M.N.*, **98**, 520, 1938.

of the so-called Southern Stream, owing to their selection, merely reflected the solar motion and could hardly be considered as a moving cluster in the sense that the Taurus Cluster, for example, is regarded.

It is to be emphasised that the O and B stars concerned are *selected* according to one criterion—and one criterion only—namely, the convergence of the great circles, defined by their proper motions, towards a point (the convergent point) which turns out, as the entries in Table I show, to be in close proximity to the solar antapex.

If the Southern Stream is assumed to be a real moving cluster, it ought to be possible to apply one or more additional criteria to substantiate this hypothesis. If, however, a second criterion is definitely negative as regards the bulk of the stars considered, the conception of the "Southern Stream" must be abandoned. The procedure in applying further criteria is similar to the methods adopted in my recent paper * on the Ursa Major Cluster. An important result of the method is the determination, for each star of the "stream," of its own appropriate value of K—if the existence of the "stream" is established.

3. So far as I am aware, Plaskett and Pearce have not published the details of the *individual* stars which they consider to form the Southern Stream; consequently, I have used, as the basis of calculation, the 160 stars of Rasmuson's list. These are divided between the various spectral subdivisions (on the Harvard classification) as shown below; the last line gives the corresponding numbers of stars used in determining the convergent point:

O–B2	B3	B5	B8, B9	*A*	Total
24	53	26	41	16	160
19	42	17	34	13	125

As the table shows, there are 103 stars of types between O and B5 and of these 87 are to be found in the catalogue † of radial velocities which formed the foundation of Plaskett and Pearce's investigation. Thus, of the 132 members of the Southern Stream, we have a very representative sample of 87 stars, the defect consisting probably of the fainter and more distant stars whose proper motions, being presumably smaller than those of the stars considered here, will exhibit, owing to accidental error, the features of convergency less plainly. It is to be remarked that Plaskett and Pearce exclude spectral types later than B7 on the Victoria classification. In my solution for the convergent point I have included 47 stars later than B5; as the convergency of the proper motions of all the stars concerned is remarkably close, the restriction of the stars to spectral types O to B5 would, presumably, have made little substantial alteration to the co-ordinates of the convergent point. As a check on this conclusion, consider the difference $\Delta\theta \equiv$ observed position angle of the proper motion minus the position angle as calculated from the adopted co-ordinates of the convergent point. Of the 78 O to B5 stars used in the solution, 39 stars have positive values of

* *M.N.*, **99**, 41, 1939.
† *Publ. D.A.O.*, **5**, No. 2, 1931.

$\Delta\theta$ averaging 6°·9 per star, while the remaining 39 stars have negative values of $\Delta\theta$ averaging 6°·5 per star (two residuals are zero ; one is assigned to the group with positive residuals and the second one to the other group). The values of $\Delta\theta$ are given in Table II. The average value of $\Delta\theta$ in Plaskett and Pearce's reduction is stated to be 15°.

The serial numbers of the stars in Table II and elsewhere in the paper follow the order of the stars in Rasmuson's list, except in one or two instances when the order of the right ascensions (as for 1950·0) is altered owing to precession. The H.D. numbers in Table V are a further aid to identification.

The proper-motion components, $\mu_\alpha \cos\delta$ and μ_δ, were obtained from Boss's *General Catalogue* ; the probable errors of these quantities and the spectral types were taken from the same source.

The individual values of $\mu_\alpha \cos\delta$ and μ_δ were corrected separately by means of the two sets of formulæ * given by Wilson and Raymond, namely :

Formulæ (i) :

$$\Delta\mu_\alpha \cos\delta = +0^s{\cdot}00016 \cos\delta - 0^s{\cdot}00025 \sin\alpha \sin\delta,$$
$$\Delta\mu_\delta = -0''{\cdot}0038 \cos\alpha.$$

Formulæ (ii) :

$$\Delta\mu_\alpha \cos\delta = +0^s{\cdot}00024 \cos\delta - 0^s{\cdot}00028 \sin\alpha \sin\delta - 0^s{\cdot}00015 \cos\alpha \sin\delta,$$
$$\Delta\mu_\delta = -0''{\cdot}0042 \cos\alpha + 0''{\cdot}0022 \sin\alpha.$$

The first pair of formulæ are based only on the precessional corrections derived in their investigation on the solar motion using the *G.C.* proper motions, while the second pair involve, in addition, the galactic rotational effects. Actually, these formulæ are to some extent inaccurate, as has been recently pointed out by Miss Williams † and acknowledged by Wilson and Raymond in a note following Miss Williams's paper. However, the formulæ represent the best corrections to the Boss system of proper motions at present available which are derivable from the internal evidence furnished by the *G.C.* itself. Although the actual corrections from the two sets of formulæ differ to some extent, the positions of the convergent point, derived from the proper motions corrected in the two ways, are practically identical.

From the corrected proper motions the total proper motion, μ, and the position angle, θ, of the proper motion were first calculated for the individual stars. The values of θ, obtained from the application of Wilson and Raymond's second set of formulæ, are given in the third column of Table II. (The entries in the second column will be referred to later.) The next column gives the probable errors of the values of θ ; these were found simply by assuming that, for any given star, the probable errors of $\mu_\alpha \cos\delta$ and μ_δ are identical and equal to their mean, as given in the *G.C.* The fifth column gives the weight, P, assigned to each value of θ in the subsequent calculations, according to the scheme :

P.E. of θ :	0° to 3°·5 ;	3°·6 to 7°·0 ;	7°·1 to 12°·0 ;	> 12°.
Weight, P :	3	2	1	0.

* *A.J.*, 47, 57, 1938.
† *A.J.*, 48, 84, 1939.

The sixth column of the table gives the value of the position angle calculated for the adopted position of the convergent point. The next column gives the residuals, $\Delta\theta$, to the nearest degree.

TABLE II

Position Angles, θ, of the Proper Motions

No.	Group	θ Obs.	P.E. ±	Wt. P	θ Cal.	$\Delta\theta$	No.	Group	θ Obs.	P.E. ±	Wt. P	θ Cal.	$\Delta\theta$
		°	°		°	°			°	°		°	°
1	1	316·2	5·9	2	314	+ 2	46	10	245·8	4·9	2	241	+ 5
2	2	266·4	5·5	2	263½	+ 3	47†	...	228·1	4·4	2	246	−18
3	3	304·5	6·8	2	285	+19	48	10	230·2	4·5	2	241	−11
4†	3	319·5	10·3	1	285	+34	49	10	241·8	2·0	3	242	0
5	2	285·1	11·5	1	263½	+22	50	9	228·8	3·5	2	233	− 4
6	3	285·6	6·6	2	285	+ 1	51	10	233·6	5·9	2	238½	− 5
7	2	292·6	10·5	1	269	+24	52	9	230·6	4·1	2	234½	− 4
8	3	281·0	4·6	2	290	− 9	53	10	245·0	5·2	2	239	+ 6
9†	...	296·6	9·7	1	264	+33	54	...	254·8	9·7	1	239	+16
10†	...	303·7	14·8	0	278	+26	55	10	242·1	7·3	1	240½	+ 2
11†	...	302·5	10·5	1	270	+32	56	10	230·7	8·6	1	239½	− 9
12	4	280·5	4·9	2	281	− 1	57	10	235·0	7·0	1	237	− 2
13	4	284·7	7·9	1	270	+15	58	10	252·6	3·1	3	235½	+17
14†	5	286·7	14·3	0	262	+25	59	10	229·4	4·8	2	235	− 6
15	5	259·6	6·2	2	264	− 4	60	10	243·4	4·5	2	235	+ 8
16	5	256·4	3·9	2	254½	+ 2	61	12	231·5	3·8	2	236	− 5
17	5	258·7	11·2	1	258	+ 1	62	12	234·9	4·0	2	237½	− 3
18†	5	279·8	3·9	2	252	+28	63	11	243·4	5·3	2	240	+ 3
19	5	246·2	3·7	2	258	−12	64	12	229·8	5·7	2	234	− 4
20	5	247·6	7·1	1	258	−10	65	12	219·3	9·4	1	236	−17
21	...	240·8	7·2	1	255½	−15	66	12	238·7	7·7	1	236	+ 3
22	6	258·4	4·7	2	262	− 4	67	12	230·2	5·8	2	230	0
23	...	246·6	5·0	2	255	− 8	68	12	223·9	4·8	2	230	− 6
24	7	249·5	5·1	2	244	+ 5	69	12	242·7	7·5	1	231	+12
25	7	233·4	6·5	2	243	−10	70	12	225·0	9·6	1	231½	− 7
26	7	246·0	2·8	3	244	+ 2	71	13	228·5	4·9	2	228	+ 1
27	...	223·4	3·2	3	241½	−18	72	13	225·0	5·3	2	228	− 3
28	7	251·0	9·8	1	240	+11	73	13	211·4	6·0	2	227	−16
29	7	241·8	3·8	2	245	− 3	74	15	230·2	3·8	2	228	+ 2
30	8	250·6	3·1	3	247	+ 4	75	14	221·4	2·8	3	226½	− 5
31	8	247·1	4·6	2	249	− 2	76	14	241·9	3·8	2	226½	+15
32	8	242·9	4·8	2	245	− 2	77	15	225·9	6·9	2	227	− 1
33	9	249·8	5·5	2	236½	+13	78	13	233·1	1·6	3	226½	+ 7
34†	...	256·7	5·2	2	236½	+20	79	13	230·6	4·8	2	226	+ 5
35†	...	226·6	3·9	2	247½	−21	80	13	230·2	3·9	2	226	+ 4
36	...	235·1	2·9	3	247½	−12	81	15	221·4	2·5	3	228	− 7
37	8	244·1	3·8	2	247½	− 3	82	13	222·4	5·7	2	224	− 2
38	10	247·1	4·6	2	242	+ 5	83†	15	246·4	6·0	2	224	+22
39	10	229·8	4·7	2	241	−11	84	...	215·5	18·3	0	227	−12
40	9	237·3	4·5	2	237	0	85	...	212·0	13·6	0	223½	−12
41	...	260·1	3·4	3	251	+ 9	86	14	221·5	4·0	2	222	− 1
42	11	247·0	4·8	2	248½	− 2	87	14	215·0	3·7	2	221	− 6
43	9	236·8	3·3	3	236	+ 1	88	13	227·4	3·6	2	220	+ 7
44	10	246·5	9·1	1	243	+ 4	89	...	227·1	3·3	3	220	+ 7
45	10	239·0	4·2	2	241	− 2	90	...	231·0	2·6	3	219½	+12

TABLE II—*continued*

No.	Group	θ Obs.	P.E. ±	Wt. P	θ Cal.	Δθ	No.	Group	θ Obs.	P.E. ±	Wt. P	θ Cal.	Δθ
		°	°		°	°			°	°		°	°
91†	...	236·7	4·9	2	219	+18	126	21	199·0	3·1	3	208	− 9
92	16	222·5	4·2	2	219	+ 4	127	...	211·4	3·5	3	207	+ 4
93	17	214·8	4·2	2	219	− 4	128	21	198·4	2·1	3	208	−10
94	16	215·4	5·1	2	217	− 2	129	...	219·8	5·4	2	206½	+13
95†	...	242·1	5·4	2	217	+25	130	22	193·0	1·8	3	207	−14
96†	...	241·4	7·3	1	216	+25	131	22	213·7	3·8	2	207	+ 7
97	16	225·0	1·8	3	216	+ 9	132	21	198·4	6·6	2	207	− 9
98	16	213·2	4·9	2	216	− 3	133	23	207·2	3·6	2	205	+ 2
99	17	216·9	5·3	2	216	+ 1	134	22	195·4	4·0	2	206	−11
100	...	227·4	4·7	2	215½	+12	135	24	196·4	4·4	2	204	− 8
101	18	218·7	8·2	1	214½	+ 4	136	23	203·3	3·2	3	205	− 2
102	...	228·2	4·7	2	214	+14	137	22	198·4	2·4	3	206	− 8
103	18	214·9	4·5	2	213	+ 2	138	21	201·5	4·3	2	205	− 4
104	18	214·1	6·8	2	213	+ 1	139	24	213·5	3·9	2	203	+11
105	18	209·7	7·4	1	212½	− 3	140	24	202·7	4·5	2	203	0
106†	...	233·1	7·4	1	212	+21	141	21	187·1	4·9	2	203	−16
107	19	199·2	5·6	2	213	−14	142	21	197·8	2·7	3	203	− 5
108	20	215·4	4·0	2	212	+ 3	143	24	208·2	9·4	1	202	+ 6
109	20	217·4	3·4	3	211	+ 6	144†	...	173·4	4·9	2	202	−29
110	18	206·6	3·3	3	210	− 3	145†	...	220·2	5·0	2	201	+19
111	19	210·2	7·3	1	212	− 2	146	22	197·4	5·6	2	202	− 5
112†	19	228·5	4·5	2	210	+19	147	21	193·5	5·1	2	201	− 8
113	20	203·4	3·3	3	209	− 6	148	23	202·3	6·6	2	200	+ 2
114	20	213·7	5·0	2	209	+ 5	149	21	197·8	3·0	3	200	− 2
115	20	214·5	5·3	2	208½	+ 6	150†	...	217·9	8·5	1	197	+21
116†	...	235·3	4·3	2	208	+27	151	25	204·3	5·6	2	196	+ 8
117	21	209·4	3·8	2	208	+ 1	152	25	204·1	5·5	2	196	+ 8
118	21	199·5	3·0	3	209	−10	153	25	185·2	3·3	3	194	− 9
119	21	204·5	3·5	3	209	− 5	154	...	202·4	7·5	1	193	+ 9
120	21	218·0	4·2	2	209	+ 9	155	...	202·4	7·3	1	190	+12
121	21	205·2	5·4	2	209	− 4	156†	...	210·0	1·5	3	189	+21
122	21	201·8	5·7	2	209	− 7	157	...	202·9	1·3	3	188	+15
123	19	201·7	2·9	3	207	− 5	158†	...	203·4	3·9	2	186	+17
124	22	209·8	5·9	2	209	+ 1	159†	...	216·0	5·7	2	181	+35
125	21	199·1	4·8	2	207	− 8	160†	...	199·4	2·9	3	176	+23

As a final preliminary to the derivation of the convergent point the stars were arranged, as far as possible, into groups according to their positions in the sky; in most cases a group area is comprised within 10° of right ascension and of declination. An early trial had indicated that 35 of the 160 stars had, very possibly, residuals $\Delta\theta$ amounting to 20° or more; these were discarded in the formation of the groups, the details of which are given in Table III below. The allocation of the stars to the several groups (25 in number) is indicated in the second column of Table II.

4. The method employed for determining the position of the convergent point is that of Bohlin. Let (α, δ) denote the adopted co-ordinates for a group and θ the adopted value of the mean position angle of the proper motions for the stars in the group. If (a, d) is that pole, with northerly

declination, of the great circle through (α, δ) defined by θ, the values of a and d are found from the formulæ

$$\cot (a - \alpha) = \sin \delta \tan \theta, \tag{2}$$

$$\sin d = \cos \delta \sin \theta. \tag{3}$$

Owing to the convention adopted with regard to d, we take θ in these equations to be the position angle if the latter lies between 0° and 180°, and to be the position angle less 180° if the position angle lies between 180° and 360°.

Theoretically, the poles (a, d) for the different groups lie on a great circle one of whose poles (A, D) is the convergent point. The equation of this great circle can be written in the form

$$lx + my + n = 0, \tag{4}$$

where

$$l = \cos a \cos d, \qquad m = \sin a \cos d, \qquad n = \sin d, \tag{5}$$

and

$$x = \cos A \cot D, \qquad y = \sin A \cot D. \tag{6}$$

(4) is the equation of condition given by each group, the values of x and y being obtained from a least-squares solution in the usual way.

Let P denote the weight of an individual value of the observed position angle (the values of P are given in the fifth columns of Table II). The adopted co-ordinates (α, δ) and the value of the position angle, θ, for a given group are found by weighting the stars of the group according to the values of P. These are shown in columns 2, 3 and 4 of Table III. The fifth column gives the sum, ΣP, of the weights, P. The weights assigned to the several groups are shown in column 6; they are based on the simple scheme:

ΣP:	2, 3;	4–7;	8–14;	> 14.
Weight:	½	1	2	3.

The values of a and d, calculated according to the formulæ (2) and (3), are shown in columns 8 and 9, and the values of l, m and n, calculated by means of (5), are given in the last three columns.

TABLE III

Summary of Groups

Group	α	δ	θ	ΣP	Wt.	$\Delta\theta$	a	d	l	m	n
	°	°	°			°	°	°			
1	121·9	−68·5	316·2	2	½	0	170·2	14·7	−0·952	0·164	0·254
2	132·9	−42·1	277·6	4	1	+12	144·2	47·4	549	396	736
3	134·4	−57·2	294·5	7	1	+ 7	162·9	29·5	832	256	492
4	154·6	−67·0	281·9	3	½	+ 5	167·5	22·5	902	200	383
5	171·3	−59·5	259·0	10	2	− 3	158·6	29·9	807	316	498
6	179·3	−78·0	258·4	2	½	− 4	167·4	11·8	956	213	204
7	181·6	−49·4	243·8	10	2	0	148·7	35·7	693	421	584
8	184·3	−60·4	246·7	9	2	0	158·0	27·0	826	334	454
9	189·1	−37·5	236·7	11	2	+ 1	141·9	41·5	589	462	663
10	191·7	−53·7	240·0	28	3	+ 1	156·1	30·8	785	348	512

TABLE III—*continued*

Group	α	δ	θ	ΣP	Wt.	$\Delta\theta$	a	d	l	m	n
	°	°	°			°	°	°			
11	193·2	−68·2	245·2	4	1	+ 1	166·7	19·7	−0·916	0·216	0·337
12	200·9	−55·8	230·5	14	2	− 2	156·0	25·7	823	367	434
13	209·1	−43·9	226·5	17	3	+ 1	155·3	31·5	775	357	522
14	210·9	−33·4	224·6	9	2	0	149·4	35·9	697	412	586
15	209·6	−55·7	229·9	9	2	+ 2	164·0	25·5	868	249	430
16	222·4	−43·8	219·0	8	2	+ 3	163·7	27·0	855	250	454
17	222·3	−35·0	215·9	4	1	− 1	154·9	28·7	795	372	480
18	229·9	−44·4	211·8	9	2	0	163·4	22·1	887	265	376
19	234·3	−59·6	208·8	8	2	− 1	169·7	14·1	954	174	244
20	232·9	−34·9	212·4	12	2	+ 2	162·9	26·1	858	264	440
21	245·7	−28·2	199·7	36	3	− 1	165·3	17·3	923	243	297
22	241·7	−19·4	200·5	14	2	− 5	158·8	19·3	880	342	330
23	243·0	−34·7	204·1	7	1	+ 1	167·3	19·6	918	207	336
24	242·7	−53·6	203·3	7	1	0	171·8	13·6	962	139	235
25	253·4	−35·1	194·7	6	1	+ 1	172·0	12·0	968	136	208

The normal equations obtained from the equations of condition, (4), weighted according to the scheme just outlined, are

$$\begin{aligned} 28{\cdot}004x - 9{\cdot}847y - 14{\cdot}153 &= 0 \\ -\ 9{\cdot}847x + 4{\cdot}043y + \ 5{\cdot}786 &= 0, \end{aligned}$$

from which

$$\begin{aligned} x &= +0{\cdot}0152 \pm 0{\cdot}0311 \\ y &= -1{\cdot}3941 \pm 0{\cdot}0820. \end{aligned}$$

The values of A and D calculated according to (6) are

$$A = 90°{\cdot}6 \pm 1°{\cdot}3\,; \qquad D = -35°{\cdot}7 \pm 1°{\cdot}7.$$

A similar calculation was performed using the values of θ obtained by correcting the proper-motion components according to Wilson and Raymond's first pair of formulæ given in § 3. The results were

$$A = 91°{\cdot}8\,; \qquad D = -37°{\cdot}9.$$

Taking a straight mean between the two solutions and attaching the probable errors obtained in the first solution, we take, as the adopted co-ordinates of the convergent point,

$$\begin{aligned} A &= \ 91°{\cdot}2 \pm 1°{\cdot}3, \\ D &= -36°{\cdot}8 \pm 1°{\cdot}7. \end{aligned} \qquad (7)$$

The corresponding solutions with the groups given equal weight are added for comparison; they are

$$(90°{\cdot}7,\ -35°{\cdot}2) \quad \text{and} \quad (90°{\cdot}9,\ -36°{\cdot}9).$$

5. Having found the convergent point we can now calculate the angular distance, λ, of each star and of each group from this position. In the same way we obtain the position angle, θ, with respect to the convergent point, for each star and each group. To minimise the vast amount of computing

involved in the calculation of λ and θ for 160 stars and 25 groups, the values of these angles were found for right ascensions 8^h, 9^h, . . . and declinations $-20°$, $-30°$, . . . Curves were then drawn from which the values of λ and θ corresponding to any position (α, δ) were read to the nearest half degree.

The seventh column of Table III gives, to the nearest degree, the difference $\Delta\theta$ between the adopted position angle for a group and the value derived in the way indicated. It will be noticed that the values of $\Delta\theta$ are satisfactorily small, with the exception perhaps of groups 2 and 3, which happen to be of relatively low weight.

Table II gives similarly the differences $\Delta\theta$ for the individual stars. The 35 stars, discarded before the final solution was undertaken, are easily recognised by the absence of a group allocation in the second column of Table II. Most of these stars have residuals exceeding 15°; a few show comparatively small residuals, and these stars could have been incorporated advantageously in the final solution. However, as very little change in the values of A and D given by (7) may be anticipated by their inclusion—or by the rejection of one or two stars of the original selection which turn out to have larger residuals than were expected—no further calculation of the co-ordinates of the convergent point was undertaken.

If we accept as a reasonable criterion for membership of the cluster—if such a cluster exists—that the great circles defined by the directions of the observed proper motions should pass within 15° of the convergent point, we have the maximum value of $\Delta\theta$ for stars satisfying this criterion given by

$$\sin \Delta\theta = \sin 15° \operatorname{cosec} \lambda.$$

With the values of λ known for each star we can readily pick out the stars not conforming to this criterion. They are indicated by a dagger in Table II. It will be seen that only 23 stars out of the full list of 160 do not comply with the condition indicated, and of these 19 had been discarded before the final solution for the convergent point was undertaken.

The average value of $\Delta\theta$ for all the 160 stars is 9°·2; Plaskett and Pearce's criterion for membership of the "cluster" was such that the average value for $\Delta\theta$ came out as 15°. The largest $\Delta\theta$ in Table II is 35°; the largest for Plaskett and Pearce's stars was 70°. These more satisfactory features of the present investigation are due in great part to the increased accuracy of the *G.C.* proper motions over those of the *P.G.C.*

Although no exception could reasonably be taken to the discarding of a star from possible membership of the "cluster" if $\Delta\theta$ exceeded 5, or even 4, times the probable error of the observed position angle, and having also in mind the somewhat generous criterion adopted by Plaskett and Pearce, I propose to accept the assumption that all the 160 stars, without exception, show the kind of convergency of their proper motions familiar in the case of such a moving cluster as that in Taurus.

6. We now derive the "stream-velocity" V still on the hypothesis that the stars form a cluster.

If p is the parallax of a star whose total proper motion is μ,

$$V \sin \lambda = \kappa\mu/p, \tag{8}$$

where $\kappa = 4{\cdot}74$.

Spectroscopic parallaxes are available for most of the stars in the list; these have been taken from Schlesinger's *General Catalogue of Stellar Parallaxes* (1935). Trigonometrical parallaxes are almost non-existent.

Formula (8) can now be used as an equation of condition for determining V, both μ and λ being known for each star, in addition to p. The requisite data are given in Table IV, which, for convenience, is arranged according to spectral type. The second column contains the values of μ obtained from the proper-motion components corrected by Wilson and Raymond's second pair of formulæ. The third column contains the values of λ, the angular distance of a star from the convergent point given by (7). The fourth column gives the spectroscopic parallaxes taken from Schlesinger's Catalogue, and the fifth column shows the values of the parallaxes calculated by means of (8) when the adopted value (18·8 km./sec.) is substituted. The sixth column gives the residuals in the sense $\frac{\kappa\mu}{p} - 18{\cdot}8 \sin \lambda$, p having here the spectroscopic value. The penultimate column gives the apparent magnitude, and the last column the absolute magnitude, M, derived from the calculated value of the parallax.

Several stars do not appear in Schlesinger's Catalogue; a few have parallaxes less than 0″·005 and these were omitted in the derivation of V.

TABLE IV

Calculation of V and M

(a) *Spectral Types* O *to* B2

No.	μ (Unit 0″·001)	λ	Parallax Spectr. (Unit 0″·001)	Parallax Cal.	Residual (km./sec.)	m	M Cal.
		°					
36	40	60	15	11	−3·7	1·58	−3·2
37	41	60	15	12	−3·4	2·09	−2·5
49	47	63½	12	14	+1·9	1·50	−2·8
56	28	66	2	8	...	5·58	+0·1
67	31	73	12	8	−5·8	2·56	−2·9
70	27	71	...	7	...	6·30	+0·6
71	35	81½	7	9	+5·1	3·53	−1·7
72	30	81	9	8	−2·8	3·32	−2·2
78	75	79	13	19	+8·9	3·06	−0·6
81	33	71	15	9	−7·4	0·86	−4·4
84	17	67½	3	5	...	5·88	−0·7
92	33	84	9	8	−1·3	2·89	−2·6
97	65	89	12	16	+6·9	2·81	−1·2
126	34	110	12	9	−4·3	3·00	−2·2
128	32	113	11	8	−4·7	2·54	−2·9

TABLE IV—*continued*

No.	μ (Unit 0″·001)	λ	Parallax Spectr. (Unit 0″·001)	Parallax Cal.	Residual (km./sec.)	m	M Cal.
130	27	116½	7	8	+1·5	2·90	−2·6
131	32	116½	7	9	+4·9	5·06	−0·2
134	30	116	8	8	+0·9	4·13	−1·4
142	29	113½	9	8	−1·9	3·08	−2·4
149	29	112	9	8	−2·1	2·91	−2·6
150	34	83½	2	9	...	5·76	+0·5
152	32	103	7	8	+3·4	3·64	−1·8
158	33	104	9	9	−0·8	2·51	−2·7
159	27	93	7	7	−0·5	3·90	−1·8
			(b) *Spectral Type* B3				
6	26	37	13	11	− 1·8	3·56	−1·2
7	26	36	...	11	...	5·92	+1·1
8	42	38	13	17	+ 3·7	4·18	+0·3
9	27	36	16	12	− 3·0	5·15	+0·5
10	11	38	17	5	− 8·5	2·63	−3·9
26	39	63	15	11	− 4·5	2·88	−1·9
28	31	67½	3	8	...	5·62	+0·1
29	47	62½	15	14	− 1·9	4·20	−0·1
30	39	60½	17	11	− 5·5	3·08	−1·7
31	49	59	14	14	+ 0·5	4·26	0·0
38	55	65	13	15	+ 3·5	5·04	+0·9
39	34	65½	10	9	− 1·0	4·16	−1·1
42	36	58½	15	11	− 4·6	2·94	−1·8
47	39	60	11	11	+ 0·5	3·26	−1·5
48	55	65	14	15	+ 1·6	4·86	+0·7
53	34	65½	9	9	+ 0·8	4·26	−1·0
54	34	65½	9	9	+ 0·8	5·46	+0·2
55	38	64½	13	11	− 3·2	4·84	+0·1
59	46	72½	10	12	+ 3·9	4·96	+0·4
60	34	71½	7	9	+ 5·2	4·40	−0·8
64	43	71½	...	11	...	5·70	+0·9
65	28	67	9	8	− 2·5	6·51	+1·0
73	42	78½	...	11	...	5·87	+1·1
79	36	82½	9	9	+ 0·3	4·05	−1·2
80	39	81	13	10	− 4·4	4·17	−0·8
82	31	84½	8	8	− 0·3	4·54	−0·9
83	43	75	...	11	...	5·20	+0·4
90	48	87	12	12	+ 0·2	2·65	−2·0
93	44	92	10	11	+ 2·1	4·09	−0·7
98	31	90	11	8	− 5·4	3·35	−2·1
99	40	98½	6	10	+13·0	5·45	+0·4
101	32	88½	9	8	− 1·9	4·39	−1·1
102	51	89	9	13	+ 8·1	4·92	+0·5
106	30	90	11	8	− 5·9	3·74	−1·7
108	38	96½	8	10	+ 3·8	4·69	−0·3

TABLE IV—*continued*

No.	μ (Unit 0″·001)	λ	Parallax Spectr. (Unit 0″·001)	Parallax Cal. (Unit 0″·001)	Residual (km./sec.)	m	M Cal.
		°					
110	36	95	13	9	− 5·6	2·95	−2·3
113	40	105	17	10	− 7·1	3·80	−1·2
117	37	110	13	10	− 4·2	4·77	−0·2
118	33	114½	6	9	+ 9·0	5·06	−0·2
119	36	110½	14	10	− 5·4	4·66	−0·3
121	38	111½	4	10	...	5·36	+0·4
125	28	107½	9	6	− 3·2	4·02	−2·1
127	42	100	9	11	+ 3·6	3·64	−1·2
133	42	101½	14	10	− 4·2	4·33	−0·7
137	32	117½	8	9	+ 2·2	4·29	−0·9
138	35	110½	9	9	+ 0·8	4·70	−0·5
146	34	120	5	10	+15·9	4·85	−0·1
147	30	114	8	8	+ 0·6	4·87	−0·6
148	24	105	7	6	− 1·9	4·33	−1·8
151	34	103	11	9	− 3·6	3·09	−2·1
154	37	84½	5	9	+16·4	5·88	+0·6
157	85	93	15	21	+ 8·0	2·97	−0·4
160	54	97	11	14	+ 4·6	3·76	−0·5
			(c) *Spectral Type* B5				
1	35	36	11	15	+ 4·0	4·46	+0·3
4	28	32	11	13	+ 2·1	5·04	+0·6
5	27	34	14	12	− 1·4	5·54	+0·9
11	13	43	9	5	− 5·9	3·70	−2·8
13	20	47	12	7	− 5·8	3·58	−2·2
16	34	54½	7	11	+ 7·7	4·26	−0·5
17	20	54	5	6	+ 3·8	5·54	−0·6
21	38	55½	5	12	+20·5	5·10	+0·5
24	43	63	8	12	+ 8·7	4·81	+0·2
35	50	60	...	14	...	5·14	+0·9
41	47	56½	12	15	+ 2·9	4·04	−0·1
66	33	67	9	9	+ 0·3	4·62	−0·6
75	56	88½	7	14	+19·1	4·72	+0·4
76	66	88½	7	17	+25·9	6·17	+2·3
85	19	75	10	5	− 9·2	4·41	−2·1
86	47	88	11	12	+ 1·5	4·55	0·0
91	42	82	14	11	− 4·4	4·14	−0·7
94	38	88	14	10	− 5·9	4·49	−0·5
100	34	87	10	9	− 2·7	4·02	−1·2
107	49	78½	13	13	− 0·5	4·54	+0·1
114	43	101	11	11	0·0	4·82	0·0
120	40	111	5	11	+20·4	5·44	+0·6
124	32	115½	...	9	...	5·90	+0·7
129	47	100	11	12	+ 1·7	4·97	+0·4
143	32	90½	12	8	− 6·2	5·49	0·0
144	26	115½	...	7	...	5·22	−0·5

TABLE IV—*continued*

(d) *Spectral Types* B8, B9

No.	μ (Unit 0″·001)	λ	Parallax Spectr. (Unit 0″·001)	Parallax Cal. (Unit 0″·001)	Residual (km./sec.)	m	M Cal.
		°					
2	47	30	...	24	...	5·17	+2·1
3	39	32	9	18	+ 9·6	5·67	+1·9
12	27	46	18	9	+ 2·0	3·56	−1·9
15	39	52	14	12	− 1·8	5·52	+0·9
18	65	56½	17	20	+ 2·4	4·82	+1·3
19	37	54	31	12	− 9·5	3·34	−1·3
22	40	53	17	13	− 3·8	5·05	+0·6
32	48	62	15	14	− 1·4	5·59	+1·3
33	40	72½	12	11	− 2·1	5·42	+0·6
34	39	72½	10	10	+ 0·6	5·77	+0·8
40	33	71½	11	9	− 3·6	5·60	+0·4
43	62	72½	14	16	+ 3·1	4·79	+0·8
44	25	62½	9	7	− 3·5	5·02	−0·7
45	52	65	10	15	+ 7·6	6·23	+2·1
46	44	65	8	12	+ 9·1	6·25	+1·6
52	50	75	8	13	+11·4	6·14	+1·7
57	37	69	13	10	− 4·1	5·29	+0·3
61	56	69½	12	15	+ 4·5	5·96	+1·8
62	57	67½	17	16	− 1·5	4·76	+0·8
63	38	61½	16	11	− 5·2	4·95	+0·2
68	72	72½	11	19	+13·1	5·65	+2·0
69	37	70½	11	10	− 1·8	5·53	+0·5
74	62	74½	...	16	...	5·68	+1·7
77	42	75½	12	11	− 1·6	5·84	+1·0
87	37	96½	14	9	− 6·2	5·00	−0·3
88	68	85	16	17	+ 1·5	5·49	+1·6
95	38	93	3	10	...	5·11	+0·1
96	50	86	9	13	+ 7·5	5·78	+1·3
103	52	87½	20	13	− 6·5	4·36	−0·1
105	32	93½	13	8	− 7·2	5·78	+0·3
111	36	67	13	10	− 4·2	5·76	+0·8
115	42	101	15	11	− 5·2	5·61	+0·8
116	63	85	13	16	+ 4·2	5·96	+2·0
122	32	111	3	9	...	5·93	+0·7
132	38	113½	10	10	+ 0·8	5·94	+0·9
136	71	104½	12	18	+ 9·8	5·58	+1·9
139	67	92½	11	17	+10·1	5·36	+1·5
145	59	82½	10	15	+ 9·4	5·78	+1·7
153	55	109	17	15	− 2·5	5·06	+0·9
155	37	98½	16	9	− 7·7	5·10	−0·1
156	112	83	22	28	+ 5·4	3·79	+1·0

TABLE IV—*continued*

(e) *Spectral Types* Ao *to* A3

No.	μ (Unit 0″·001)	λ	Parallax Spectr. (Unit 0″·001)	Parallax Cal. (Unit 0″·001)	Residual (km./sec.)	m	M Cal.
		°					
14	21	51	...	7	...	5·42	−0·3
20	37	54½	...	12	...	5·08	+0·5
23	48	56	11	15	+ 5·1	5·42	+1·3
25	39	64	14	11	− 3·7	5·58	+0·8
27	76	66	...	21	...	5·93	+2·5
50	42	78	16	11	− 6·0	5·01	+0·2
51	39	67½	...	11	...	5·90	+1·1
58	67	71	20	18	− 2·0	5·02	+1·3
89	76	81	...	19	...	5·52	+1·9
104	40	87½	...	10	...	7·17	+2·2
109	64	94½	16	16	+ 0·3	5·38	+1·4
112	58	85	14	15	+ 0·9	5·48	+1·4
123	95	79	...	24	...	5·96	+2·9
135	64	82½	16	16	+ 0·4	5·79	+1·8
140	60	82½	...	15	...	5·86	+1·7
141	32	114	14	9	− 6·4	4·76	−0·5

The least-squares solutions of (8) according to spectral type, together with the average residual r, are given as follows:—

	O–B2	B3	B5	B8, B9	A	O–B5	O–B9
No.	20	47	23	37	8	90	127
V	18·7	19·6	22·1	19·6	17·2	20·0	19·9
r	3·6	4·2	6·3	5·2	3·1	4·8	4·8

In these solutions all stars with parallaxes of 0″·005 and over have been included.

Reference to Table IV shows that several stars—Nos. 146 and 154 (B3) and Nos. 21, 75, 76 and 120 (B5)—have numerical residuals exceeding 14 km./sec., with that of No. 76 outstandingly large; four of these stars have parallaxes of 0″·005, and the parallaxes of the remaining two are 0″·007. In making the final solutions, No. 76 has been discarded and the remaining 5 stars with large residuals have been given half weight.

Keeping only the stars of types O to B5, we find that $V = 18{\cdot}7$ km./sec. For all types O to B9, $V = 18{\cdot}9$. We adopt as the solution of (8)

$$V = 18{\cdot}8 \pm 0{\cdot}3, \qquad (9)$$

the average residual for stars of types O to B5 being now 4·3.

As errors in the small parallaxes produce a disproportionately large effect in the calculation of V, a system of weighting depending on the values of p might have been introduced into the least-squares solutions. However, as most of the residuals shown in Table IV are reasonably small (with the

exception of the 6 stars already referred to), especially for stars with parallaxes exceeding 0″·007, very little change may be anticipated in the value of V in (9).

We remark that the adopted value of V is applicable to the O to B5 stars if we decide to consider them separately, as in Plaskett and Pearce's investigation; the inclusion of the B8 and B9 stars makes no appreciable change in the "stream-velocity."

If we accept the value of V in (9) as substantially accurate, then, remembering that the stars are assumed to form a cluster, the residuals in column 6 of Table IV must arise from errors in p, μ and λ. On the average, the probable error of μ is numerically about one-tenth the value of μ, and unless the position of the convergent point given by (7) is seriously in error the effect of an error in λ will be unappreciable. As a rough estimate, then, the probable error of a calculated value of p will be, on the average, numerically about one-tenth of its value. For a given star a serious discrepancy between the observed and calculated parallaxes—this discrepancy would be reflected as a numerically large residual in column 6—would suggest that on the observational evidence assembled such a star ought not to be considered a member of the cluster. With this criterion in mind, one or two stars with extremely small spectroscopic parallaxes and a few more with large residuals may be suspected of having no real connection with the "stream." However, with these possible exceptions the main bulk of the stars in the list for which spectroscopic parallaxes are known are to be provisionally regarded as members of the cluster.

7. We consider briefly the criterion provided by the absolute magnitudes given in Table IV, taking first the O–B2 stars (with the exception of 4 stars these belong, in almost equal proportions, to the B1, B2 subdivisions). The results assembled by Plaskett and Pearce * of the investigations on absolute magnitude by Charlier, Robb, Adams, Edwards, Gerasimovič, Oort and Strömberg show that the mean absolute magnitude of such stars is about $-2{\cdot}5$ with a dispersion of 1·2 about the mean. The data of Table IV (*a*) show that the mean absolute magnitude $\bar{M}$ is $-1{\cdot}8$ (or, omitting the four faintest stars, $-2{\cdot}3$) with an average residual of 1·0, equivalent to a dispersion of 1·2.

The other spectral groups give, similarly, an approximate accordance with what is known of the absolute magnitudes of the B stars. The results are summarised below (σ denotes the dispersion):

	O–B2	B3	B5	B8, B9	A
$\bar{M}$	−1·8	−0·6	−0·2	+0·9	+1·3
σ	1·2	1·1	1·0	0·9	0·9

The conclusion reached by applying the absolute magnitude criterion is that our results are *not* hostile to the assumption that the stars in Rasmuson's list belong to a moving stream.

8. We now discuss the radial velocities of Rasmuson's stars; the

* *M.N.*, 94, 699, 1934.

criterion which they provide is crucial in determining the real kinematical characteristics of the Southern Stream.

In Table V the stars are arranged according to spectral types ; we still include types B8, B9 and A. The second column gives the H.D. number. The observed radial velocities and their probable errors are given in the third and fifth columns respectively. The entries for type O to B5 are taken from the Victoria Catalogue * of radial velocities, except for a few stars —indicated by an asterisk—the data for which are taken from Moore's Catalogue.† The latter source also supplies all the information relating to the B8, B9 and A stars. The letter *V* in the column of probable errors indicates that the radial velocity is variable, and when followed by an interrogation mark that it is suspected of being variable.

In Plaskett and Pearce's investigation, which was based substantially on the data in the Victoria Catalogue, radial velocities with probable errors exceeding 5·3 km./sec. numerically were ignored ; also, all stars with numerical values of the residual radial velocity, obtained by removing the parallactic component, exceeding 45 km./sec. were similarly excluded ; adopting these principles, I give such stars zero weight in Table V.

TABLE V

Radial Velocities

(a) *Spectral Types* O *to* B2

No.	H.D.	Radial Velocity				K_1	C	K	v_1	v_2
		Obs.	Cal.	P.E. Obs. ±	Wt.					
36	108248	+16·3	+9·4	5·7	0	+ 6·9	−1·4	+ 8·3	+ 2·2	+ 2·5
37	108249	+31·9	+9·4	2·5	2	+22·5	−1·3	+23·8	+17·8	+18·0
49	111123	+20·0	+8·4	0·5 *V*	3	+11·6	−1·1	+12·7	+ 6·9	+ 6·9
56	112244	+24·0	+7·6	3·9	1	+16·4	−2·0	+18·4	+11·7	+12·6
67	118716	+ 5·6	+5·5	0·9	3	+ 0·1	−2·1	+ 2·2	− 4·6	− 3·6
70*	119159	−48	+6·1	4 *V*?	0	−54	−2·4	−52	−59	−58
71	120307	+ 8·9	+2·8	0·5	3	+ 6·1	−1·7	+ 7·8	+ 1·4	+ 2·0
81	122451	−12·3	+6·1	7·3 *V*	0	−18·4	−1·9	−16·5	−23·1	−22
84*	124471	−20	+7·2	4 *V*?	1	−27	−3·3	−24	−32	−30
92	129056	+ 7·3	+2·0	0·6 *V*	3	+ 5·3	−1·9	+ 7·2	+ 0·6	+ 1·4
97	132058	− 0·3	+0·3	1·6 *V*	2	− 0·6	−0·9	+ 0·3	− 5·3	− 5·5
126	143018	− 3·0	−3·3	...	1	+ 0·3	−0·6	+ 0·9	− 4·4	− 4·9
128	143275	−15·4	−3·3	5·7 *V*	0	−12·1	−0·4	−11·7	−16·8	−17·5
130	144217	− 9·3	−8·4	1·5	2	− 0·9	−0·2	− 0·7	− 5·6	− 6·5
131	144218	− 4·3	−8·4	2·5	2	+ 4·1	−0·2	+ 4·3	− 0·6	− 1·5
134	144470	− 6·4	−8·2	1·3	2	+ 1·8	−0·2	+ 2·0	− 2·9	− 3·8
142	147165	− 0·4	−7·5	1·1	2	+ 7·1	−0·4	+ 7·5	+ 2·4	+ 1·7
149	149438	+ 0·6	−7·0	0·3	3	+ 7·6	−0·4	+ 8·0	+ 2·9	+ 2·2
150	150898	−55·5	+2·1	2·6	0	−58	−1·5	−56	−63	−62
152	151985	+ 2·0	−4·2	0·7 *V*?	3	+ 6·2	−0·8	+ 7·0	+ 1·5	+ 1·2
158	160578	−10·0	−4·5	4·4 *V*	1	− 5·5	−1·1	− 4·4	−10·2	−10·2
159	165024	+ 3·1	−1·0	1·7	2	+ 4·1	−0·3	+ 4·4	− 0·6	− 1·4

* *Publ. D.A.O.*, 5, No. 2, 1931 ; the Catalogue incorporates results for a certain number of stars not observed at Victoria. † *Lick Publ.*, 18, 1932.

TABLE V—*continued*

(b) *Spectral Type* B3

No.	H.D.	Radial Velocity Obs.	Cal.	P.E. Obs. ±	Wt.	K_1	C	K	v_1	v_2
6	79351	+23·1	+15·0	...	1	+ 8·1	−0·6	+ 8·7	+ 2·3	+ 1·8
7*	79275	+ 7·3	+15·2	2·6	1	− 7·9	−0·1	− 7·8	−13·7	−14·7
8	79447	+16·6	+14·8	0·5	3	+ 1·8	−0·4	+ 2·2	− 4·0	− 4·7
9	79735	+31·9	+15·2	3·7	1	+16·7	0·0	+16·7	+10·9	+ 9·8
10	81188	+21·7	+14·8	...	1	+ 6·9	−1·0	+ 7·9	+ 1·1	+ 1·0
26	105435	+ 5	+ 8·5	5	1	− 3	−1·3	− 2	− 9	− 9
28*	105521	0	+ 7·2	3 *V*?	1	− 7·2	−1·6	− 5·6	−13·0	−12·5
29*	105937	+21	+ 8·7	3	1	+12	−1·0	+13	+ 6	+ 6
30	106490	+26·4	+ 9·2	1·1	2	+17·2	−1·4	+18·6	+11·4	+11·7
31	106983	+18·7	+ 9·7	1·0	3	+ 9·0	−1·1	+10·1	+ 3·2	+ 3·2
38	108257	+24·0	+ 8·0	7·5	0	+16·0	−1·0	+17·0	+10·2	+10·1
39	108483	+12·0	+ 7·8	6·0	0	+ 4·2	−1·6	+ 5·8	− 1·6	− 1·1
42	109668	+18·1	+ 9·8	3·8	1	+ 8·3	−1·4	+ 9·7	+ 2·5	+ 2·8
47	110879	+42	+ 9·4	8 *V*	0	+33	−1·4	+34	+27	+27
48	110956	+16·7	+ 8·0	1·0	3	+ 8·7	−1·0	+ 9·7	+ 2·9	+ 2·8
53	112092	+11·9	+ 7·8	1·0	3	+ 4·1	−1·8	+ 5·9	− 1·7	− 1·0
54	112091	+18·6	+ 7·8	2·5	2	+10·8	−1·8	+12·6	+ 5·0	+ 5·7
55	112078	+16·1	+ 8·0	2·6	1	+ 8·1	−1·5	+ 9·6	+ 2·3	+ 2·7
59	113703	+ 9·2	+ 5·7	3·6	1	+ 3·5	−1·3	+ 4·8	− 2·3	− 2·1
60	113791	+14·3	+ 6·0	0·6	3	+ 8·3	−1·8	+10·1	+ 2·5	+ 3·2
64*	115823	+ 6·2	+ 6·0	1·1	2	+ 0·2	−1·5	+ 1·7	− 5·6	− 5·2
65*	116072	− 7	+ 7·3	4	1	−14	−2·1	−12	−20	−19
73*	120640	− 6	+ 3·7	4 *V*	1	−10	−1·4	− 9	−16	−16
79	121743	+ 7·4	+ 2·5	0·7	3	+ 4·9	−1·7	+ 6·6	− 0·9	− 0·3
80	121790	+ 6·8	+ 2·9	1·7	2	+ 3·9	−1·6	+ 5·5	− 1·9	− 1·4
82	122980	+12·1	+ 1·8	0·5	3	+10·3	−1·9	+12·2	+ 4·5	+ 5·3
83	124367	+19·3	+ 4·9	2·2	2	+14·4	−1·5	+15·9	+ 8·6	+ 9·0
90	127972	− 0·2	+ 1·0	1·5	2	− 1·2	−1·2	0·0	− 7·0	− 6·9
93	129116	+ 8·5	− 0·7	2·2	2	+ 9·2	−1·2	+10·4	+ 3·4	+ 3·5
98	132200	+ 9·1	0·0	0·5	3	+ 9·1	−1·7	+10·8	+ 3·3	+ 3·9
99	132955	+ 5·5	− 2·8	0·6	3	+ 8·3	−1·1	+ 9·4	+ 2·5	+ 2·5
101	133955	+18·1	− 0·5	4·4	1	+17·6	−1·8	+19·4	+11·8	+12·5
102	134687	+11·2	+ 0·3	4·1	1	+10·9	−1·1	+12·0	+ 5·1	+ 5·1
106	136504	+ 4·5	0·0	2·9	1	+ 4·5	−1·7	+ 6·2	− 1·3	− 0·7
108	136664	− 1·2	− 2·1	1·4	2	+ 0·9	−1·1	+ 2·0	− 4·9	− 4·9
110	138690	+ 6·3	− 1·6	5·3	1	+ 7·9	−1·3	+ 9·2	+ 2·1	+ 2·3
113	139365	+ 0·5	− 4·9	7·5	0	+ 5·4	−0·8	+ 6·2	− 0·4	− 0·7
117	141637	+ 9·3	− 6·4	3·8	1	+15·7	−0·5	+16·2	+ 9·9	+ 9·3
118	142096	+ 0·1	− 7·8	5·9	0	+ 7·9	−0·3	+ 8·2	+ 2·1	+ 1·3
119	142114	−12·2	− 6·6	1·3	2	− 5·6	−0·5	− 5·1	−11·4	−12·0
121	142184	−27	− 6·9	...	1	−20	−0·5	−20	−26	−27
125	142669	+ 2·8	− 5·7	0·3	3	+ 8·5	−1·1	+ 9·6	+ 2·7	+ 2·7
127	143118	+ 7·2	− 3·3	2·1	2	+10·5	−0·9	+11·4	+ 4·7	+ 4·5
133	144294	+14·6	− 3·7	1·2	2	+18·3	−0·9	+19·2	+12·5	+12·3
138	145482	+ 8·8	− 6·6	3·5	1	+15·4	−0·5	+15·9	+ 9·6	+ 9·0

TABLE V—*continued*

No.	H.D.	Radial Velocity Obs.	Cal.	P.E. Obs. ±	Wt.	K_1	C	K	v_1	v_2
146	148184	− 8·1	− 9·4	1·8	2	+ 1·3	+0·1	+ 1·2	− 4·5	− 5·7
147	148605	− 3·8	− 7·6	1·7	2	+ 3·8	−0·2	+ 4·0	− 2·0	− 2·9
148	148703	+ 0·4	− 4·9	1·6 *V*	2	+ 5·3	−1·0	+ 6·3	− 0·5	− 0·6
154*	153716	+ 6·0	+ 1·8	1·4	2	+ 4·2	−1·4	+ 5·6	− 1·6	− 1·3
157	158427	− 2·2	− 1·0	2·9	1	− 1·2	−0·4	− 0·8	− 7·0	− 7·7
160	169467	− 0·8	− 2·3	0·5 *V*?	3	+ 1·5	−0·3	+ 1·8	− 4·3	− 5·1

(c) *Spectral Type* B5

1	68520	+ 9·6	+15·2	0·2	3	− 5·6	−0·5	− 5·1	−10·4	−11·1
4	74560	+21·6	+15·9	1·0	3	+ 5·7	−0·2	+ 5·9	+ 0·9	− 0·1
5	77475	+33·7	+15·6	3·5	1	+18·1	+0·1	+18·0	+13·3	+12·0
11	86440	+14·1	+13·8	0·4	3	+ 0·3	−1·4	+ 1·7	− 4·5	− 4·3
13	91465	+26·0	+12·8	1·9	2	+13·2	−1·5	+14·7	+ 8·4	+ 8·7
16	98718	+15·6	+10·9	3·2	1	+ 4·7	−1·1	+ 5·8	− 0·1	− 0·2
17*	99556	+ 9·4	+11·0	1·5	2	− 1·6	−2·2	+ 0·6	− 6·4	− 5·4
21	103079	+25·5	+10·6	1·2	2	+14·9	−1·2	+16·1	+10·1	+10·1
24	105382	+16·5	+ 8·5	1·0	3	+ 8·0	−1·2	+ 9·2	+ 3·2	+ 3·2
35	108250	+26·8	+ 9·4	5·6	0	+17·4	−1·1	+18·5	+12·6	+12·5
41	109026	+14·2	+10·4	3·4	1	+ 3·8	−1·0	+ 4·8	− 1·0	− 1·1
66	116087	+26·2	+ 7·3	8·0	0	+18·9	−1·9	+20·8	+14·1	+14·8
75	120709	+13·8	+ 0·5	0·6	3	+13·3	−0·9	+14·2	+ 8·5	+ 8·2
76*	120710	+ 1·2	+ 0·5	2·7	1	+ 0·7	−0·8	+ 1·5	− 4·1	− 4·5
85	125288	+ 4·6	+ 4·9	0·9 *V*?	3	− 0·3	−3·3	+ 3·0	− 5·1	− 3·0
86	125823	+ 8·7	+ 0·7	0·7	3	+ 8·0	−1·2	+ 9·2	+ 3·2	+ 3·2
91	128345	+14·3	+ 2·6	2·0	2	+11·7	−1·5	+13·2	+ 6·9	+ 7·2
94	130807	+ 7·0	+ 0·7	0·9	3	+ 6·3	−1·4	+ 7·7	+ 1·5	+ 1·7
100	133242	+16·6	+ 1·0	2·3	2	+15·6	−1·6	+17·2	+10·8	+11·2
107	136415	−17·2	+ 3·7	1·5	2	−20·9	−1·2	−19·7	−25·7	−25·7
114	140008	+ 8·5	− 3·6	2·5 *V*	2	+12·1	−0·9	+13·0	+ 7·3	+ 7·0
120	142165	+13·2	− 6·7	10	0	+19·9	−0·4	+20·3	+15·1	+14·3
129	143699	− 0·2	− 3·3	3·8	1	+ 3·1	−0·8	+ 3·9	− 1·7	− 2·1
143	147152	− 8·9	0·0	3·6	1	− 8·9	−1·5	− 7·4	−13·7	−13·4
144	147933	−12·9	− 8·1	4·5	1	− 4·8	−0·2	− 4·6	− 9·6	−10·6

(d) *Spectral Types* B8, B9

2	74067	+21·1	+16·3	0·9	3	+ 4·8	+0·2	+ 4·6	+ 3·4	+ 2·1
3	74535	+19·8	+15·9	1·8	2	+ 3·9	−0·1	+ 4·0	+ 2·5	+ 1·5
12	89080	+ 4	+13·1	4	1	− 9	−1·3	− 8	−10	−10
15	97583	+20·8	+11·6	2·7	1	+ 9·2	−1·1	+10·3	+ 7·8	+ 7·8
18	100673	+ 4	+10·4	4	1	− 6	−0·6	− 5	− 7	− 8
19	100841	+ 7·9	+11·0	2·0	2	− 3·1	−1·1	− 2·0	− 4·5	− 4·5
22	104174	+22	+11·3	4	1	+11	−1·1	+12	+10	−10
32	107696	+ 0·7	+ 8·8	2·0	2	− 8·1	−1·1	− 7·0	− 9·5	− 9·5
33	107832	−10·0	+ 5·7	2·1	2	−15·7	−1·1	−14·6	−17·1	−17·1
34	108114	−11·4	+ 5·7	0·6	3	−17·1	−1·2	−15·9	−18·5	−18·4

TABLE V—*continued*

No.	H.D.	Radial Velocity Obs.	Cal.	P.E. Obs. ±		Wt.	K_1	C	K	v_1	v_2
40	108541	+ 5	+ 6·0	4		1	− 1·0	−1·4	+ 0·4	− 2·4	− 2·1
43	110073	+15·1	+ 5·7	1·9	*V*	2	+ 9·4	−0·9	+10·3	+ 8·0	+ 7·8
44	110335	+11·8	+ 8·7	2·2		2	+ 3·1	−2·2	+ 5·3	+ 1·7	+ 2·8
45	110461	+37	+ 8·0	8	*V*?	0	+29	−1·0	+30	+28	+28
46	110506	+10·3	+ 8·0	1·4		2	+ 2·3	−1·3	+ 3·6	+ 0·9	+ 1·1
52	111774	+ 4·7	+ 4·9	1·0		3	− 0·2	−1·1	+ 0·9	− 1·6	− 1·6
57	112409	+25	+ 6·7	4		1	+18	−1·6	+20	+17	+18
63	114911	+ 5	+ 9·0	10	*V*?	0	− 4	−1·5	− 3	− 5	− 6
68	118991	+ 2	+ 5·7	7		0	− 4	−0·9	− 3	− 5	− 6
69	118978	−29·7	+ 6·3	1·6		2	−36·0	−1·7	−34·3	−37·4	−36·8
74	120642	+26·6	+ 5·1	2·4		2	+21·5	−1·0	+22·5	+20·1	+20·0
77	121190	+ 8·0	+ 4·7	2·0		2	+ 3·3	−1·5	+ 4·8	+ 1·9	+ 2·3
87	126769	+ 5·5	− 2·0	2·4		2	+ 7·5	−1·2	+ 8·7	+ 6·1	+ 6·2
88	126981	+10	+ 1·6	4		1	+ 8	−0·9	+ 9	+ 7	+ 7
95	131120	+ 5·4	− 1·0	1·3		2	+ 6·4	−1·3	+ 7·7	+ 5·0	+ 5·2
103	135734	+14·8	+ 0·8	1·4		2	+14·0	−1·1	+15·1	+12·6	+12·6
105	135876	+16	− 1·1	5	*V*	1	+17	−1·6	+19	+16	+16
111	138800	−19·0	+ 7·3	1·2		2	−26·3	−1·6	−24·7	−27·7	−27·2
115	140784	− 5	− 3·6	3		1	− 1·4	−0·8	− 0·6	− 2·8	− 3·1
116	141168	+20·7	+ 1·6	0·5		3	+19·1	−0·9	+20·0	+17·7	+17·5
139	145842	+ 2·0	− 0·8	2·3		2	+ 2·8	−0·7	+ 3·5	+ 1·4	+ 1·0
153	153613	+15	− 6·1	4		1	+21	−0·2	+21	+20	+18
155	157243	+ 8	− 2·8	4		1	+11	−0·8	+12	+10	+ 8
156	158094	+12	+ 2·3	3		1	+10	−0·4	+10	+ 9	+ 6
				(e) *Spectral Type* A							
14	96919	−22·4	+11·8	0·5		3	−34·2	−1·8	−32·4		
20	101379	+ 4	+10·9	4	*V*	1	− 6·9	−1·2	− 5·7		
23	104878	+23	+10·5	3		1	+13	−1·0	+14		
25	105416	+ 6·5	+ 8·2	...		0	− 1·7	−1·2	− 0·5		
50	111597	+18	+ 3·9	4		1	+14	−1·4	+15		
58	113314	−10	+ 6·1	3		1	−16	−0·9	−15		
89	126983	+ 3·5	+ 2·9	2·9		1	+ 0·6	−0·8	+ 1·4		
109	136933	− 7·6	− 1·5	1·5		2	− 6·1	−0·8	− 5·3		
112	139129	−11·9	+ 1·6	1·7		2	−13·5	−1·0	−12·5		
135	144480	0	+ 2·5	4		1	− 2·5	−0·9	− 1·6		
141	147084	− 8·5	− 7·6	0·8		3	− 0·9	−0·3	− 0·6		

In the sixth column are the weights assigned to each radial velocity in the subsequent discussion, given according to the simple scheme :

P.E. :	0–1·0 ;	1·1–2·5 ;	2·6–5·3 ;	> 5·3.
Weight :	3	2	1	0.

If the stars form a cluster, moving with space-velocity V, the observed radial velocities, ρ, should then be given in the first instance accurately by $V \cos \lambda$, ignoring observational errors. But as we are dealing mainly with

B-type stars, the systematic effect, known as the K term, must be added to $V \cos \lambda$, the value of K being presumably a constant for each spectral type. Further, the stars of the "stream" are spread over a considerable extent of galactic longitude so that to the radial velocity of each star, whose galactic co-ordinates are denoted by (G, g), must be added the variable effect, due to differential galactic rotation and designated by C, given by

$$C = rA \sin 2(G - G_0) \cos^2 g, \tag{10}$$

in which r is the star's distance in parsecs, A is Oort's constant and G_0 is the longitude of the galactic centre. We take A to be 0·017 km./sec./parsec, the mean of the values given by Oort * and Plaskett and Pearce †, and G_0 to be 325°, which is substantially the value derived in the two investigations just quoted.

The values of C are given in column 8 of Table V; they were derived by a process similar to that described in § 5 for obtaining the individual values of λ and θ. Owing to the limits of longitude within which the stars are situated, the values of C are, with one or two exceptions, negative.

The formula for the observed radial velocity, ρ, of a star in the "stream" is now

$$\rho = V \cos \lambda + C + K, \tag{11}$$

or, on writing

$$K_1 = C + K, \tag{12}$$

we have

$$\rho = V \cos \lambda + K_1. \tag{13}$$

If it is argued that a moving cluster should not be affected by galactic rotation if it is to remain a cluster, we must regard K_1 in (13) as constant and equal to the K term for the spectral type concerned. We shall find it immaterial to the result of our conclusions whether we adopt (11) or (13) as the basis of our arguments.

The term $V \cos \lambda$ which appears in (11) and (13) is calculated for each star with the value of V—18·8—given by (9) and with the appropriate value of λ given in Table IV; the values of $V \cos \lambda$ are given in the fourth column of Table V under the heading "Cal."

The corresponding values of K_1 and K can then be written down from the entries in columns 3, 4 and 8; they are given in the seventh and ninth columns respectively.

9. We consider the formulæ (11) and (13) more specifically. The values of the term $V \cos \lambda$ come from sources entirely independent of radial velocity considerations. As we have seen, we have derived the convergent point of the "stream" on the assumption that such a stream exists. If the stream is a reality, the convergence of the great circles defined by the position angles, θ, of the proper motions is a necessary consequence of this hypothesis. If, on the other hand, the "stream" is illusory, we have, nevertheless, *selected* a certain number of stars (160 in all) *which, so far as*

* *B.A.N.*, **4**, 82, 1927.
† *M.N.*, **94**, 679, 1934.

their proper motions are alone concerned, behave precisely as members of a moving cluster. In either event we have derived the convergent point with a satisfactory degree of precision, and we can therefore take it that the probable errors of the quantity cos λ are comparatively trifling. Combining the probable error of V given in (9), the values of V cos λ given in the fourth column of Table V may be expected to have probable errors very much less in magnitude than the average probable error of the radial velocities. Incidentally, if we regard the position of the convergent point as accurate, an error of, say, 1 km./sec. in V would lead to an error of but a fraction of this amount in V cos λ, on the average, as most of the values of λ lie between 60° and 120°.

Consider formula (11) and ignore galactic rotation so that K_1 is the K term which will be given for each star by (13). If K_1 has to have any meaning arising from physical or other causes, it must be presumed to be a constant for a given spectral subdivision ; further, as the stars are supposed to form a stream the values of K_1 derived from the individual stars must all be equal, at any rate within the limits of the observational errors in the observed radial velocities, ρ, which will be the predominant errors in (13).

In the same way, if we must include the effects of galactic rotation, the values of K derived from (11) must all, theoretically, be equal.

The entries under the headings K_1 and K in Table V show, at any rate at a first glance, that this is not even approximately the case.

10. Still assuming that the stars form a cluster, we must suppose that the variations in K_1 and K given in Table V are due to accidental errors in the observed radial velocities. Equations (13) and (11) are then equations of condition for determining the real values of K_1 and K, which we shall denote by $\bar{K}_1$ and $\bar{K}$. The equations have been solved by least squares, each spectral subdivision being treated separately in two different ways : (*a*) by weighting the equations according to the system of weights shown in column 6 of Table V, and (*b*) by giving each star unit weight, omitting, however, those stars with zero weight. This double solution has been undertaken as there is no indication as to how Plaskett and Pearce weighted the radial velocities ; the presumption, however, is that each star carried unit weight. The solution has been carried out for the A stars, although this procedure is obviously absurd in their case.

Let v_1 and v_2 denote the residuals $K_1 - \bar{K}_1$ and $K - \bar{K}$ formed for each star ; their values are to be found in the last two columns of Table V. We denote by $\bar{v}_1$ and $\bar{v}_2$ the weighted (or unweighted) means of the residuals v_1 and v_2 taken without regard to sign. The results of the solutions, together with the probable errors, are shown in Table VI, the weighted results being shown opposite (1) in the table and the unweighted opposite (2).

11. Let us first consider the data in Table V (*e*) relating to the A stars. There are 10 stars with assigned weights ; membership of the cluster involves that each value of K_1—or, alternatively, of K—should be zero within the limits of observational error (we assume, as is generally found for these stars, that the K term is negligible, ignoring the obviously absurd values of $-8{\cdot}9$ and $-7{\cdot}9$ for $\bar{K}_1$ and $\bar{K}$ shown in Table VI). Three of

TABLE VI

		O–B2	B3	B5	B8, B9	A
$\bar{K}_1$	(1)	+4·7 ± 1·6	+5·8 ± 0·9	+4·8 ± 1·5	+1·4 ± 1·7	−8·9 ± 3·8
	(2)	+3·5 ± 1·4	+5·2 ± 0·9	+4·4 ± 1·4	+2·6 ± 1·5	...
$\bar{K}$	(1)	+5·8 ± 1·6	+6·9 ± 1·0	+6·0 ± 1·6	+2·5 ± 1·7	−7·9 ± 3·6
	(2)	+4·6 ± 1·4	+6·2 ± 0·8	+5·6 ± 1·3	+3·6 ± 1·5	...
$\bar{v}_1$	(1)	5·1	5·3	6·8	10·2	...
	(2)	6·6	6·4	7·1	9·8	...
$\bar{v}_2$	(1)	5·2	5·5	6·6	10·1	...
	(2)	6·6	6·5	7·0	9·8	...

these stars fulfil the required condition (perhaps fortuitously), but there can be no doubt about the others ; they can *not* be members of the "cluster." Rasmuson's list of 160 stars should, accordingly, be purged of the A-type stars. It is to be noted that the abolition of the A stars depends simply on the application of the radial velocity criterion.

Let us now turn our attention to the stars of one of the other spectral subdivisions, say the O–B2-type stars, and let us consider the unweighted solution with galactic rotation ignored ; the appropriate entries in Table V (*a*) are under the headings K_1 and v_1. The formal solution of (13) gives (see Table VI)

$$\bar{K}_1 = +3{\cdot}5 \text{ km./sec.} \qquad (14)$$

This value of $\bar{K}_1$ represents the systematic positive effect for the stars concerned and must be regarded as the K term for the sample of stars under consideration. But the condition of cluster-motion implies that all the residuals v_1 should be zero within the limits of observational error. It only requires a glance at the v_1 column in Table V (*a*) to see that this condition is very far from being fulfilled.

Moreover, the v_1 residuals yield a further important point, for the mean value, $\bar{v}_1$, of these residuals taken without regard to sign is 6·6 km./sec. The interpretation of this result is simply that the group of O–B2 stars forms a system in which, after the systematic effects due to V and the K term have been removed, the individual stars have random radial speeds whose mean value is 6·6 km./sec.

Considering the solutions with galactic rotational effects introduced, the unweighted solution for $\bar{K}$ is

$$\bar{K} = +4{\cdot}6 \text{ km./sec.}, \qquad (15)$$

which is about 1 km./sec. higher than the value in (14) for $\bar{K}_1$. Referring to (12) this merely indicates that the mean value of C in (12) for the stars concerned is numerically about 1 km./sec., an approximation which holds for all the spectral subdivisions, as reference to Table VI shows. The table also shows that the values of $\bar{v}_1$ and $\bar{v}_2$ are, as might be anticipated, practically identical.

12. In dealing with all the stars of types O–B5 together, we consider only the unweighted solutions, as these correspond to the practice adopted probably in most, if not all, of other investigations of a like nature. The

results, weighting according to the numbers of stars and dropping the suffix from the v residuals, are

$$\bar{K}_1 = +4{\cdot}6, \qquad \bar{K} = +5{\cdot}7 \qquad \text{and} \qquad \bar{v} = 6{\cdot}6. \tag{16}$$

The only interpretation of our results is that our stars, 85 in number, reveal a K term of $+4{\cdot}6$ km./sec. or, if we insert the rotational corrections, of $+5{\cdot}7$ km./sec., and that the mean random radial speed, obtained by correcting the observed radial velocities for the common velocity V and K term, is 6·6 km./sec. Before discussing the interpretation of V, we consider the mean residual $\bar{v}$. This is a quantity that can be obtained from statistical studies of B stars in such problems as those connected with the solar motion and galactic rotation. Sometimes such investigations omit the B8, B9 stars as these stars are regarded as more properly belonging to the A stars; other investigations deal with all the subdivisions from Bo to B9. Taking all the 116 stars with assigned weights in Table V between O and B9, the results for $\bar{K}_1$, $\bar{K}$ and $\bar{v}$ are as follows (as before, the subdivisions are weighted according to the numbers of stars in these groups) :—

$$\bar{K}_1 = 4{\cdot}1\,; \qquad \bar{K} = 5{\cdot}2\,; \qquad \bar{v} = 7{\cdot}5. \tag{17}$$

Two representative results for $\bar{v}$ for the O to B5 stars are Campbell and Moore's * and Nordström's †, which are respectively 8·7 and 7·7. Our value in (16) for $\bar{v}$ is a little smaller but of much the same order of magnitude.

Considering the O to B9 stars, we have, for comparison, the results obtained by Nordström ‡ and Smart and Green § as follows : $\bar{v} = 8{\cdot}1$ and 6·0 respectively. Our value in (17) is of intermediate amount and just a little smaller than Nordström's value. Without pressing our results too closely—the number of stars on which they depend is much smaller than the numbers used in the investigations quoted—we can say at least that our results are of the magnitude appropriate to the known mean random radial speeds of the B stars.

The results for $\bar{v}$ in (16) and (17) show that the stars in Table V merely form a sample—and a fairly representative sample—of the B stars as a whole. But it may be objected that the stars in Table V are not a random sample in the sense just used; this raises the question of the interpretation of V, the "cluster-velocity."

13. The value of V—the "stream-velocity"—is, from (9), 18·8 km./sec. directed towards the convergent point $(91^\circ, -37^\circ)$ as given by (7). The solutions show that it is immaterial whether V refers to the O–B5 or to B8, B9, or to all of the B-type stars. This value of V is practically that of the solar velocity. We may quote Plaskett and Pearce's value of 19·1 obtained from their general solution.‖ I have elsewhere given results of

* *Lick Publ.*, **16**, 38, 1928.

† *Lund Medd.*, Ser. II, No. 79, p. 90, 1936 (Nordström gives the mean dispersion σ which is equivalent to $\frac{5}{4}\bar{v}$ in our notation).

‡ *Loc. cit.* (I have weighted his results given independently for the O–B5 and B8, B9 stars).

§ W. M. Smart, *M.N.*, **96**, 572, 1936.

‖ *M.N.*, **94**, 688, 1938 ; **98**, 521, 1938.

previous investigations by different authors according to varying methods; they give a mean * of 19·5 km./sec. for the solar motion with respect to stars of all spectral types; Nordström's † result is 19·6. If the stars are restricted to class B, the values of V given by Plaskett and Pearce in a comprehensive list of determinations ‡ range from 17·2 to 24·3—many of these investigations are of relative antiquity and are based on comparatively scanty data. To these results may be added Nordström's value of 20·8 (the mean of three groups) for the O–B5 stars and Smart and Green's value § of 19·6 for all B-type stars within 10° of the galactic equator (this zone includes the great majority of the stars in the present investigation).

It may fairly be granted, then, that the value of V in (9) can be identified with the solar velocity.

Considering now the position of the convergent point in (7). This position is only 7° from the usually accepted position (90°, −30°) of the solar antapex, and only 3° from the position obtained by Boss from the proper motions of the *P.G.C.*

The conclusion would seem to be irrefutable that in determining the convergent point and the "stream-velocity" we have simply determined the position of the solar antapex and the solar velocity.

This conclusion is strengthened—if further support be required—by the small probable error associated with the value, 18·8, in (9). In dealing with the general problem of the solar motion we consider an assembly of stars moving, as a system, with velocity, say V_0, relative to the Sun, each member of the system possessing random linear velocity components in three perpendicular directions. In particular, when we determine the solar motions from the observed proper-motion components, $\mu_\alpha \cos\delta$ and μ_δ, we implicitly assume that each of these values includes the parallactic component and a random component arising from the random linear velocity in the corresponding direction. The method of solution assumes that the random proper motions follow the law of errors in each of *two* perpendicular directions; this procedure is further complicated by the unknown distribution of the stars concerned as regards distance from the Sun.

Our formula (8) may be regarded as a simplified basis of the method of finding the solar velocity, the apex being derived from other considerations. If we disregard the small residuals $\Delta\theta$ in Table II we are thus dealing with an assembly of stars whose random motions in *one* direction only, that given by μ, have to be eliminated. Moreover, these stars have parallaxes, with few exceptions, lying between the limits 0″·007 and 0″·015 and for this reason they form a more ideal system than the general body of the stars for satisfying the criterion of randomness associated with the method of deriving the solar motion.

14. The main conclusion of this paper may now be stated briefly.

* *M.N.*, **96**, 476, 1936.
† *Loc. cit.*, p. 90.
‡ *Publ. D.A.O.*, **5**, No. 4, p. 249, 1936.
§ *M.N.*, **96**, 479, 1936 (Table VIII).

The stars of the so-called Scorpio-Centaurus Cluster do not form a moving cluster in the accepted sense of the term and are actually a fairly representative sample of the B-type stars in general.

If this conclusion meets with general acceptance, the Scorpio-Centaurus Cluster (the Southern Stream) must be removed from the category of moving clusters, a reputation it has enjoyed for the last quarter of a century.

15. There is an additional argument, to which we have already referred implicitly, for the conclusion stated in the previous section. As we have seen, Rasmuson's stars are spread over about 120° in galactic longitude; within this range the differential rotational effects vary by non-negligible amounts. Consequently, a group of stars, enjoying even momentarily the kinematical properties of a moving cluster, would soon be dispersed.

A further consequence is that, in deriving the solutions for the K term, the rotational terms must be included, since our collection of stars is now regarded as a sample of the B-type stars in general and not as a moving cluster. Thus the solutions for $\bar{K}$ give the appropriate values of the K term. The results from (16) and (17) are, inserting the probable errors,

$$\text{For the O–B5 stars,} \quad K = +5{\cdot}7 \pm 0{\cdot}6.$$
$$\text{For the O–B9 stars,} \quad K = +5{\cdot}2 \pm 0{\cdot}7.$$

It should be added that these results refer to the unweighted solutions.

Results of a large number of investigations are tabulated by Plaskett and Pearce.* The largest value of K shown in the table is $+5{\cdot}6$ derived by Frost, Barrett and Struve in 1926 from 350 stars of types O–B9; in 1930 Pearce arrived at the value $+5{\cdot}0$ for 78 bright O–B2 stars; otherwise most of the entries in the table are between 4 and 5 km./sec. More recently Nordström has obtained the value of $+4{\cdot}4 \pm 0{\cdot}5$ for several hundreds of the O–B5 stars (this is the simple average of results given for three groups of stars) with which may be compared Campbell and Moore's value of $+4{\cdot}9$ obtained in 1928 from 284 O–B5 stars.

My result for the O–B5 stars is thus somewhat higher—but not conspicuously so—than the results referred to; it is to be remembered that this result has been obtained from the statistical treatment of only 85 stars. I conclude that there is nothing exceptional as regards the value of the K term obtained from Rasmuson's stars. It may be added that, as a result of a comprehensive and elaborate study of radial velocities, Nordström has arrived at a similar conclusion as to the substantial normality of the O–B5 stars of Rasmuson's list in connection with the K term. Omitting these stars from his general solution he concluded † that they have very little influence in modifying the value of K and, incidentally, the value of the solar velocity.

The inference is plain; the stars of the "Southern Stream" are as normal, in respect to the K term, as the remaining stars of the spectral types considered.

* *Publ. D.A.O.*, 5, No. 4, p. 249, 1936.
† *Lund Medd.*, Ser. II, No. 79, p. 102, 1936.

I am indebted to Mr. T. R. Tannahill for his efficient assistance in carrying out some of the tedious computations which this investigation necessitated.

Summary

1. For a quarter of a century a number of B-type stars (132, according to Plaskett and Pearce) lying between galactic longitudes 210° and 330° have been believed to form a moving cluster, known as the Scorpio-Centaurus Cluster or the Southern Stream, owing to the convergence of their proper motions.

2. As a basis of investigation Rasmuson's list of 160 stars is used for deriving the position of the convergent point whose equatorial co-ordinates are found to be (91°, −37°), in close proximity to the solar antapex.

3. On the assumption that the stars form a moving cluster the "stream-velocity" is then derived by means of the observed total proper motions and spectroscopic parallaxes; this is found to be 18·8 km./sec. The parallax and absolute magnitude of each star are then calculated; the application of the absolute magnitude criterion is mostly inconclusive as to the constitution of the "cluster."

4. With the value, 18·8 km./sec., of the "stream-velocity" the "calculated" radial velocity of each star is found and compared with the observed radial velocity. The difference should, theoretically, be the K term—if the stars form a moving cluster—which is treated in two ways (*a*) as a constant, and (*b*) as affected by differential galactic rotation.

5. The result of the ensuing discussion is held to be conclusive against the conception that the stars concerned form a moving cluster; the "stream-velocity" is identified with the solar velocity and the "convergent point" with the solar antapex. The mean residual speed of the "cluster stars" is found to be of the same order of magnitude as that found in general investigations, and the K term is also found to be normal in magnitude.

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ON TRUMPLER'S STARS

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1. *Introduction.*—The theory of stellar structure leads to a relation between mass, luminosity and radius, in agreement with observation for almost all stars for which these three quantities can be directly computed from observation; and it has made possible, also, determination of the mean mass of the free particles in the stars. There is, however, one group of stars for which the usual theory encounters difficulties. This group, generally called Trumpler's stars, have very high masses, ranging from 55 to 400 times the solar mass; but their luminosities are so low that Beer and Chandrasekhar † could not find a solution for μ, the mean molecular weight. The lowest luminosities were found for $\mu = 0{\cdot}6$, for which the differences $\log L_{\text{comp}} - \log L_{\text{obs}}$ (L = luminosity) were

$$\log L_{\text{comp}} - \log L_{\text{obs}} = 0{\cdot}38,\ 1{\cdot}86,\ 1{\cdot}59,\ 2{\cdot}19,\ 1{\cdot}87,\ 2{\cdot}77,\ 1{\cdot}21$$

(in the order followed in Tables I and II). These differences in logarithms of luminosity correspond to the following differences in magnitudes:—

$$m_{\text{obs}} - m_{\text{comp}} = 1{\cdot}0,\ 4{\cdot}6,\ 4{\cdot}0,\ 5{\cdot}5,\ 4{\cdot}7,\ 6{\cdot}9,\ 3{\cdot}0.$$

Although there is an apparent discrepancy between theory and observation, the first of Trumpler's stars does not show, according to the present author's computations, any discrepancy whatever; and, further, the differences $m_{\text{obs}} - m_{\text{comp}}$ for the remaining Trumpler stars have been found to be not as large as the computations of Beer and Chandrasekhar would indicate.

2. *Absorption and Scattering in Trumpler's Stars. The Theoretical Mass-Luminosity Relation as Compared with Observation.*—It will be shown that the main part of the opacity in the interior of a Trumpler star is due to scattering by free electrons. The absorption of radiation by the atoms is negligible throughout almost the whole star. The reason for this fact is, briefly, that the temperatures in Trumpler's stars, in comparison with the densities, are high. Therefore the density of radiation is high, as compared with the ability of the atoms to absorb radiation.

The coefficient of scattering per unit mass is ‡

$$\sigma = 0{\cdot}19(1 + X), \qquad (1)$$

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† *Observatory*, 59, 168, 1936.

‡ Chandrasekhar, *An Introduction to the Study of Stellar Structure* (Chicago, 1939), p. 271. Chandrasekhar, however, gives the scattering coefficient erroneously, as he combines the absorption coefficient per unit mass with the scattering coefficient per unit volume.

while the coefficient of absorption is *

$$\kappa = [25{\cdot}59]\frac{1 - X^2}{\tau}\frac{\rho}{T^{3{\cdot}5}}, \tag{2}$$

if we assume the helium content to be comparatively low and neglect the small amount of absorption by pure hydrogen. In these formulæ X is the hydrogen abundance of the stellar mass, ρ the density, T the temperature and τ the guillotine factor. We assume as a first approximation that the star is built according to the standard model. Then its central temperature and density may be calculated from the formulæ †

$$T_c = [7{\cdot}29]\mu\beta\frac{M/M_\odot}{R/R_\odot}; \tag{3}$$

$$\rho_c = [1{\cdot}88]\frac{M/M_\odot}{(R/R_\odot)^3}, \tag{4}$$

where β is determined by the equation ‡

$$\beta^4 = \frac{1 - \beta}{0{\cdot}00309(M/M_\odot)^2\mu^4}. \tag{5}$$

$1 - \beta$ is the ratio of radiation pressure to total pressure, M and R the stellar mass and radius respectively, while $M_\odot$ and $R_\odot$ are the corresponding quantities for the Sun. Formulæ (3) and (4) give the temperature and density in degrees and gr./cm.^{3} respectively. The hydrogen content, X, may be computed approximately from the average molecular weight, μ, by means of the formula §

$$X = \frac{\frac{1}{\mu} - 0{\cdot}5}{1{\cdot}5}. \tag{6}$$

Table I gives the values of σ and of $\kappa\tau$ in the stellar centre for four values of μ—2, 1, 0·6 and 0·5. The values for the masses, luminosities and radii were taken from a list published in Chandrasekhar's book (p. 490). They are based on Trumpler's determinations of the gravitational red shift || and Kuiper's new temperature scale.¶ Table I gives σ and $(\kappa\tau)_c$, together with the central density and temperature and the value of $1 - \beta$.

B. Strömgren ** has computed the guillotine factor τ as a function of the ionisation potential ψ/kT and of the temperature. His table, however, covers temperatures only as high as 25 million degrees. For this temperature, τ is at least about 3; and for higher temperatures it appears to be still

* B. Strömgren, *Z. f. Ap.*, **7**, 255, 1933.
† Eddington, *The Internal Constitution of the Stars* (Cambridge, 1930), p. 136.
‡ Eddington, *I.C.S.*, p. 117.
§ B. Strömgren, *Z. f. Ap.*, **7**, 229, 1933.
|| *Publ. A.S.P.*, **47**, 249, 1935.
¶ *Ap. J.*, **88**, 506, 1938.
** *Z. f. Ap.*, **7**, 222, 1933; *Handbuch d. Ap.*, **7**, 125, 1936.

TABLE I

	Star	ρ_c	$\mu=2$ $X=0$				$\mu=1$ $X=0.33$			
			$\frac{1}{10^6}T_c$	$1-\beta$	$(\kappa\tau)_c$	σ	$\frac{1}{10^6}T_c$	$1-\beta$	$(\kappa\tau)_c$	σ
1	N.G.C. 2244, 15	46	126	0·74	0·078	0·19	117	0·52	0·091	0·25
2	8	19·5	105	0·80	0·064	0·19	100	0·62	0·068	0·25
3	N.G.C. 2264, 60	40	152	0·83	0·036	0·19	138	0·69	0·045	0·25
4	N.G.C. 2362, 1	3·2	72	0·88	0·040	0·19	69	0·77	0·041	0·25
5	N.G.C. 6871, 2	4·9	82	0·86	0·039	0·19	76	0·74	0·045	0·25
6	5	6·6	93	0·90	0·032	0·19	93	0·80	0·029	0·25
7	N.G.C. 7380, 1	7·8	75	0·77	0·080	0·19	69	0·58	0·098	0·25

	Star	ρ_c	$\mu=0.6$ $X=0.8$				$\mu=0.5$ $X=1$			
			$\frac{1}{10^6}T_c$	$1-\beta$	$(\kappa\tau)_c$	σ	$\frac{1}{10^6}T_c$	$1-\beta$	$(\kappa\tau)_c$	σ
1	N.G.C. 2244, 15	46	101	0·31	0·063	0·34	94	0·23	0·000	0·38
2	8	19·5	92	0·42	0·037	0·34	87	0·34	0·000	0·38
3	N.G.C. 2264, 60	40	128	0·52	0·024	0·34	124	0·44	0·000	0·38
4	N.G.C. 2362, 1	3·2	67	0·63	0·018	0·34	65	0·57	0·000	0·38
5	N.G.C. 6871, 2	4·9	72	0·59	0·022	0·34	70	0·52	0·000	0·38
6	5	6·6	89	0·68	0·014	0·34	88	0·62	0·000	0·38
7	N.G.C. 7380, 1	7·8	62	0·37	0·058	0·34	59	0·29	0·000	0·38

TABLE II

	Star	$\log\frac{M}{M_\odot}$	$\log(L/L_\odot)$			$\log L_{\mu=0.5}-\log L_{obs}$	$m_{obs}-m_{\mu=0.5}$
			Obs.	$\mu=2$	$\mu=0.5$		
1	N.G.C. 2244, 15	1·76	5·49	6·07	5·26	−0·23	−0·6
2	8	1·99	4·69	6·33	5·66	0·97	2·4
3	N.G.C. 2264, 60	2·18	5·33	6·54	5·96	0·63	1·6
4	N.G.C. 2362, 1	2·47	5·73	6·85	6·37	0·64	1·6
5	N.G.C. 6871, 2	2·35	5·33	6·72	6·21	0·88	2·2
6	5	2·60	5·01	6·99	6·53	1·52	3·8
7	N.G.C. 7380, 1	1·89	4·89	6·22	5·49	0·60	1·5

greater, as P. M. Morse's calculations also show (unpublished). Let us now use the empirical rule given by Strömgren (*Z. f. Ap.*, 7, 227, 1933) that the total opacity is found approximately by taking whichever is the larger value of the absorption and scattering, and adding to it 1·5 times the smaller. If $\tau=3$, we must accordingly add half of $(\kappa\tau)_c$ to the corresponding σ-value

to obtain the total opacity. We then see at once from the table that the total opacity is highest for the lowest mean molecular mass $\mu = 0{\cdot}5$, and that for this μ, and even for other values of μ, the absorption may be neglected in comparison to the scattering, without making a noticeable error in the computed magnitude. For this reason we write, in the usual mass-luminosity formula, σ in the place of κ. Then we have *

$$L = \frac{4\pi cGM(1-\beta)}{\alpha\sigma}. \tag{7}$$

It is further evident from the table that $1-\beta$ decreases with decreasing μ. Therefore, both the change of opacity and the change of $1-\beta$, with decreasing μ, cause the luminosity to decrease. We get the lowest luminosity for $\mu = 0{\cdot}5$—that is, for pure hydrogen.

For the quantity α, the value 2·5 was used.* This α-value was also used by B. Strömgren † in his calculations of the hydrogen content of the stars. Its adoption in our case will be discussed in section 4. When, further, L and M are expressed in solar units, we get from (7)

$$\frac{L}{L_\odot} = \frac{[3{\cdot}72]}{\sigma}\frac{M}{M_\odot}(1-\beta). \tag{8}$$

Table II gives the luminosities for $\mu = 2$ and $\mu = 0{\cdot}5$ (computed by means of this formula and Table I), together with the stellar mass. $L_{\mu=2}$ represents the theoretically highest possible luminosity, while $L_{\mu=0{\cdot}5}$ represents the theoretically lowest possible luminosity, corresponding to our assumptions. We find the best agreement with observation when $\mu = 0{\cdot}5$; the average difference $m_{obs} - m_{comp}$ is then 1·8. The average value of the minimum differences according to the calculations of Beer and Chandrasekhar is 4·2. The author's calculations therefore reduce the discrepancy between theory and observation on the average by 2·4 stellar magnitudes, *i.e.* to about four-tenths of the original discrepancy. For N.G.C. 2244, 15, even the mean molecular weight may be computed. The result is $\mu = 1$, approximately, which means that about one-third of the stellar mass is hydrogen. As long, however, as we have not been able to reduce the discrepancy between theory and observation for the whole group of Trumpler's stars, we cannot give much weight to this determination of the hydrogen content. In this connection it is interesting to notice that if we assume Trumpler's stars to be composed of pure Russell-mixture, the average difference $m_{obs} - m_{comp}$ will be 3·3. Even this is smaller than the average minimum value of $m_{obs} - m_{comp}$, 4·2, which follows from the calculations of Beer and Chandrasekhar. But in any case the differences between observed and computed values are so large that they cannot be explained as observational errors.

3. *Absorption in Comparison to Scattering in Outer Layers.*—We shall now show that the absorption is much less important than the scattering

* Eddington, *I.C.S.*, p. 124.

† *Z.f. Ap.*, **7**, 233, 1933; *Handbuch d. Ap.*, **7**, 184, 1936.

in practically the whole mass of a Trumpler star. As we assume the stars to be built according to the standard model ($\rho \propto T^3$), and that the hydrogen content is constant throughout a given star, the quantity $\kappa\tau$ (formula (2)) increases from the stellar centre as $(T_c/T)^{1/2}$. We obtain the guillotine factor, τ, from B. Strömgren's * table as a function of the ionisation potential ψ/kT, defined by the equation

$$e^{\psi/kT} = [\bar{8}\cdot 2]\frac{T^{3/2}}{\rho(1+X)}, \tag{9}$$

and of the temperature. We consider two spherical surfaces concentric with the star and with † temperatures $T = 0\cdot 21 T_c$ and $T = 0\cdot 111 T_c$. These surfaces have densities $\rho = 0\cdot 009 \,.\, \rho_c$ and $\rho = 0\cdot 0014 \,.\, \rho_c$ respectively, and the mass inside each sphere is approximately 95 per cent. and 98 per cent. respectively of the stellar mass. The ionisation potential at the surfaces varies from about 8 to 10. Then from the table we find that for all of our stars τ is about 3 at the former surface and about 2 at the latter surface. The corresponding values of $(T_c/T)^{1/2}$ are 2 and 3 approximately. As the absorption is smaller than the scattering, we derive the following approximate expressions for the total opacity: $\sigma + 1\cdot 5\frac{2}{3}(\kappa\tau)_c = \sigma + (\kappa\tau)_c$ at the former surface, and $\sigma + 1\cdot 5\frac{3}{2}(\kappa\tau)_c = \sigma + 2(\kappa\tau)_c$ at the latter. Remembering that the envelope as defined by Chandrasekhar ‡ contains 10 per cent. of the stellar mass, and comparing these expressions with the values in Table I, we see immediately that in practically the whole of this envelope, also, the scattering is much more important than the absorption. The only exception is the vicinity nearest the stellar surface, which should contain a very small fraction of the stellar mass but a comparatively large fraction of the radius. This part of the star, although it has a constitution (which determines the mass concentration of the star) very sensitive to changes in the assumed opacity law §, should not have an observable influence on the mass-luminosity relation. Therefore it is correct for our purpose to consider the opacity as constant throughout the interior of Trumpler's stars.

4. *Comparison of the Luminosities with the Luminosities of the Point-Source Model in Radiative Equilibrium.*—In order to obtain an idea regarding the adoption of $\alpha = 2\cdot 5$, the mass-luminosity law (8) was compared with the mass-luminosity law of the point-source model in radiative equilibrium. For this purpose Keenan's ‖ numerical integrations were used. It was found that, for masses comparable with the masses of Trumpler's stars, the mass-luminosity law (8) is practically identical with the mass-luminosity law of the point-source model in radiative equilibrium. (If the opacity for stars of the same order of mass is determined by the Kramers-Eddington law of absorption, the point-source model in radiative equilibrium corre-

* *Z. f. Ap.*, **7**, 224, 1933; *Handbuch d. Ap.*, **7**, 125, 1936.

† Eddington, *I.C.S.*, p. 83.

‡ *An Introduction, etc.*, p. 292.

§ Tuominen, *Ann. Acad. Scient. Fennicæ*, **A 48**, No. 16, pp. 21–32 and 68–69, 1938.

‖ Chandrasekhar, *An Introduction, etc.*, p. 350; Keenan, *Ap. J.*, **89**, 499, 1939.

sponds to $\alpha = 4{\cdot}25$.*) Keenan's models, however, cannot be convectively stable, and all point-source models must necessarily have convective cores. This means that our luminosities calculated from formula (7) with $\alpha = 2{\cdot}5$ are somewhat too low. The value $\alpha = 1$, however, must give considerably too high luminosities, as it, in our case (constant opacity coefficient, section 3), corresponds to a constant rate of generation of energy. Therefore the magnitudes calculated with the correct law of liberation of subatomic energy hardly can be more than 0·5 magnitude higher than the values given in Table II.

In this connection it is interesting to notice that not only the point-source model with constant opacity obeys the law $L \propto M$ for large masses, as was found by Keenan †, but also the standard model with constant opacity obeys the same law for large masses. This can be easily seen from formula (7) together with (5).

5. *Distribution of Trumpler's Stars in the Mass-Luminosity Diagram.*—It is interesting to plot the masses and luminosities in the same diagram with the mass-luminosity curves for pure hydrogen and for pure Russell-mixture (fig. 1). The diagram shows that the dispersion of the stars in the direction perpendicular to the curves of constant hydrogen constant is larger than the distance between the curves. This means that the discrepancy which still is left cannot be removed by adding a constant correction to the observed magnitudes. In order to get an idea how the discrepancy may be removed, we proceed by plotting the different observed and computed quantities.

6. *Possible Causes for the Discrepancy between Observed and Computed Magnitudes.*—Fig. 2 shows an apparent correlation between the spectral type ‡ and the discrepancy $m_{\text{obs}} - m_{\text{comp}}$ in stellar magnitudes. Star 7 is uncertain, as can be seen from Table II in Trumpler's original paper.§ It is true that the correlation is essentially determined by stars 1 and 6; but it is difficult to believe that this is entirely accidental, because even the radius and the mass are found to show a correlation which is not exclusively determined by stars 1 and 6. Fig. 2 indicates that the discrepancy cannot be attributed to an error in the temperature scale or in the bolometric corrections. If the temperature scale or the bolometric corrections are inaccurate, they ought to be more so for the O-stars than for the B-stars. It can be seen from fig. 2, however, that the discrepancy is larger for the stars of later type, as it vanishes at about O6 or O7. Furthermore, it is difficult to believe that inaccuracies in the absolute photographic magnitudes of Trumpler's stars are capable of producing such a systematic discrepancy, which, in addition, is correlated with the spectral type. Trumpler ‖ derived the differences between the absolute and apparent photographic magnitudes

* Eddington, *I.C.S.*, pp. 123 and 127; Eddington had $(M/M_\odot)\mu^2 = 24$ (*I.C.S.*, p. 126), which for pure hydrogen gives $\log (M/M_\odot) = 1{\cdot}98$.

† *Ap. J.*, **89**, 507, 1939.

‡ Kuiper, *Ap. J.*, **88**, 506 (Table 13), 1938.

§ *Publ. A.S.P.*, **47**, 252, 1935.

‖ *Publ. A.S.P.*, **47**, 254, 1935.

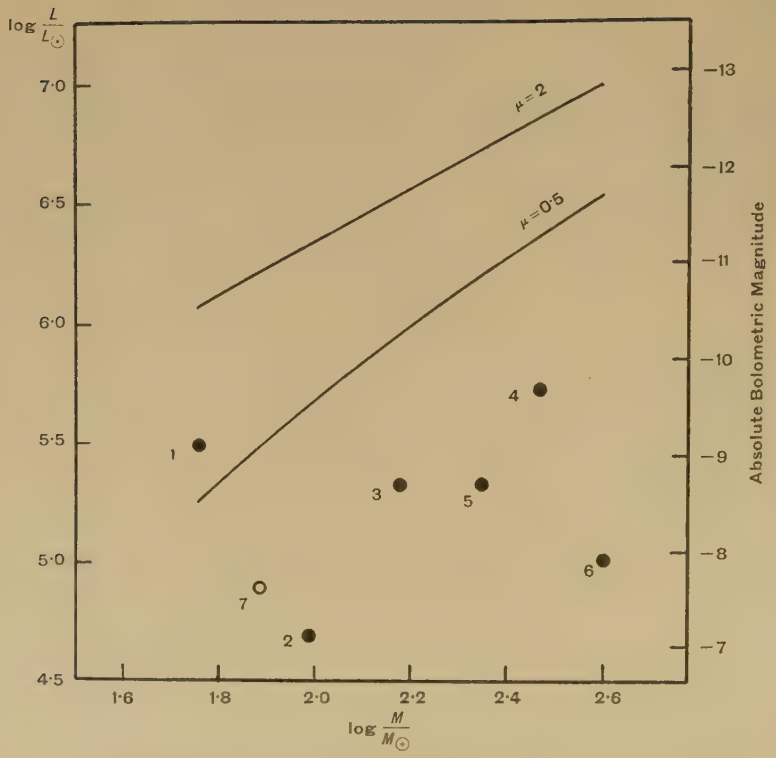

FIG. 1.—*The circles give the positions of Trumpler's stars in the mass-luminosity diagram. The numbers beside the circles indicate the order of the stars in Tables I and II. Star 7 is uncertain. The two curves give the mass-luminosity relation for pure hydrogen* ($\mu = 0{\cdot}5$) *and for pure Russell-mixture* ($\mu = 2$).

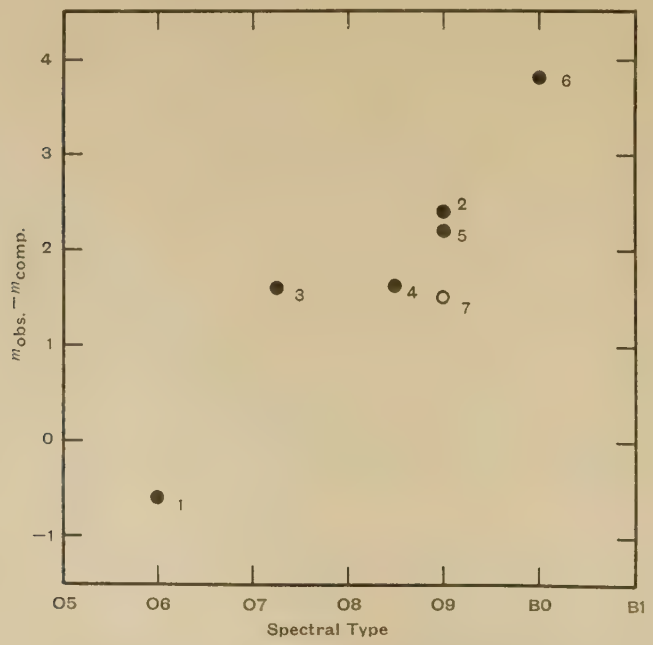

FIG. 2.—*The relation between the spectral type and the difference of observed and computed absolute bolometric magnitudes of Trumpler's stars.*

from the photographic magnitudes and spectral types of the fainter stars in the clusters. Further, fig. 2 indicates that if the method of determining stellar masses from the gravitational red-shift is erroneous, it should be less erroneous for O-stars than for B-stars.

Summary

It is shown that scattering by free electrons is a much more important source of opacity than photoelectric absorption in the interior of Trumpler's stars. When account is taken of this fact, the discrepancy between observed and computed magnitudes is reduced from the average value 4·2, which follows from the calculations of Beer and Chandrasekhar, to the average value 1·8. It appears that the discrepancy is larger for later type stars, as it vanishes for about O6–O7 stars. Possibilities for explaining the discrepancy are discussed.

I am much indebted to Professor Harlow Shapley for giving me the opportunity to work in this observatory.

Harvard College Observatory,
Cambridge, Massachusetts :
1939 *May.*

THE VARIABLE SPECTRUM OF α^2 CANUM VENATICORUM

W. S. Tai

α^2 Canum Venaticorum ($\alpha = 12^h\ 51^m{\cdot}4$, $\delta = +38^\circ\ 52'$, 1900·0) was classified as a star of spectral type A*op* by Miss Maury.* It was designated *p* because the K line of *Ca*II was "extremely faint," *Si*II 4128 and 4131 unusually strong, and "some of the fainter lines appear to be peculiar in wave-length, while others differ in intensity from the corresponding lines of the stars of the same type." Lockyer and Baxandall † verified these statements by Miss Maury, and put the star in the Markabian group of the Kensington classification, the typical star of the group being α Pegasi. Ludendorff ‡ measured the radial velocity of the star, and noted that a few faint lines in the spectrum were variable in intensity. Belopolsky § made an extensive study of the spectrum, and found two groups of lines varying periodically in a period of about 5·5 days : one group of lines strengthen while the other weaken, and *vice versa*. A few of the variable lines are, according to him, also variable in displacement. Baxandall ‖ was the first to point out that the most marked variable lines are due to europium. Thenceforth one group of the variable lines was often referred to as the Europium group, and the star was named an Europium star. Kiess ¶ attributed several lines in the other group to terbium.

Guthnick and Prager ** measured the surface luminosity of α^2CVn with their photoelectric photometer, and found the star to be a variable with a period of $5^d{\cdot}54$, the range of variation being $0^m{\cdot}051$, the comparison star being δ UMa. The formula given is as follows :—

$$\text{Light Max.} = 2{,}420{,}242{\cdot}2 + 5{\cdot}54E.$$

Anger †† claimed to have observed a good number of faint emission lines in the spectrum of α^2CVn, all of which vary in the same manner as the europium lines. Markov ‡‡ summarized the findings of different observers by listing five classes of lines : The first two are the two groups of variable lines mentioned above ; the third consists of five lines which a few observers regarded as having double maxima, and of which the most

* *Harvard Annals*, **28**, 97, 1897.

† *Proc. Roy. Soc.*, **77**, 550, 1906.

‡ *Astr. Nach.*, **173**, 1, 1906.

§ *Astr. Nach.*, **196**, 6, 1913 ; and *Bull. Acad. Imp. Sci. St. Petersburg*, **7**, 689, 1913 ; *Bull. Obs. Pulkovo*, No. 101, 1927, which includes three other papers on α^2CVn by Gerasimovič, Markov, Rossovskaya.

‖ *Observatory*, **36**, 440, 1913.

¶ *Pub. Detroit Obs.*, **3**, 106, 1923.

** *Veroff. Berlin-Babelsberg*, **1**, 44, 1914.

†† *Ap. J.*, **70**, 114, 1929.

‡‡ *Ap. J.*, **72**, 301, 1930.

marked is λ 4077·06. The fourth class consists of a few lines which vary irregularly in intensity ; while the last class contains all the constant lines. He also mentioned that in June of 1920, 18 lines were more intense than usual, and 6 lines were greatly widened.

Farnsworth * chose 16 lines for more detailed study, but did not find any good correspondence between line intensities and radial velocities. She attributed the variation of displacements of a few lines to blends. In a subsequent paper, Farnsworth † calculated the period of α^2CVn from the intensity variation of the lines λλ 4130, 4132, 4201, 4205, 4233 on 170 plates, and obtained the formula :

$$Eu\text{II Max.} = \text{J.D. } 2{,}419{,}869{\cdot}720 + 5{\cdot}46939E.$$

In the Lick Catalogue of Radial Velocities,‡ the radial velocity of α^2CVn is given as $-3{\cdot}5 \pm 0{\cdot}3$ km./sec., being the weighted mean of the observed results from six observatories. Despite the variation in displacement for a few strong variable lines the star as a whole has usually been regarded as having a constant velocity.

The Spectrograms

Forty-six spectrograms were obtained at Cambridge in the spring of 1938 and that of 1939 with the 25-inch Newall refractor. 26 were taken with the four-prism spectrograph, and the rest with the two-prism one. The dispersion is 13·2 A. per mm. at $H\gamma$ for the four-prism plates, and 18 A. per mm. at $H\delta$ (or 23·3 A. per mm. at $H\gamma$) for the two-prism plates. The Ilford Astra II plate was used for all except the four-prism plates in the D region. In that case the Ilford Hypersensitive Panchromatic plate was used. After exposure to star and iron arc, the plate was transferred to a step-slit standardizing spectrograph, and calibration marks were impressed on it. It was then developed for 5 minutes at 62° F.

A list of the spectrograms is given in Table I. The phase is calculated from Farnsworth's formula.

Identification of Lines

Three spectrograms are chosen for wave-length measurement. The measured values are corrected for the Earth's motion in the usual way, and are also corrected for the radial velocity of the star as given in the Lick Catalogue. The results are given in Table III. From λ 4119 to λ 4650, the list is mainly based on the plate F 623 ; while the plate F 651 supplies data for the region λλ 4049–4119, and T 741 for the region λλ 3900–4049.

The elements present are :

H. Very strong.
*Al*II. Many coincidences. Weakly present.
*Mg*I. 4352 and 4167 present.

* *Ap. J.*, **75**, 364, 1932.
† *Ap. J.*, **76**, 313, 1932.
‡ *Pub. Lick Obs.*, **32**, 104, 1932.

TABLE I

α^2CVn Plates

Plate No.	Date (U.T.)	J.D. 2,420,000 +	Phase d	Spectral Region
F 609	1938 Feb. 13·96	8,944·50	1·05	$H\delta$ to λ 4650
F 617 *	25·01	8,954·50	1·12	...
F 618 *	25·06	8,954·55	1·17	...
F 623 *	Mar. 2·01	8,959·51	0·66	...
F 624 *	2·09	8,959·59	0·74	...
F 631	4·07	8,961·58	2·72	...
F 634	6·11	8,963·61	4·76	...
F 645	13·92	8,971·42	1·64	...
F 648	14·92	8,972·42	2·64	...
F 651	17·98	8,975·48	0·23	...
F 655	18·98	8,976·48	1·23	λ 4040 to $H\gamma$
F 667	30·90	8,988·40	2·21	...
F 671	31·93	8,989·43	3·24	...
F 676	April 4·99	8,993·49	1·83	...
F 680	7·06	8,995·56	3·90	...
F 681 *	7·88	8,996·38	4·72	...
F 682 *	7·94	8,996·44	4·78	...
T 728	25·91	9,014·35	0·87	λ 3900 to λ 4500
T 734	May 4·88	9,023·33	4·37	...
T 738	7·88	9,026·33	1·90	...
T 740	8·89	9,027·34	2·91	...
T 741	11·89	9,030·34	0·44	...
T 744	20·89	9,039·39	3·97	λ 4000 to $H\beta$
T 745	21·88	9,040·38	4·96	...
T 747	22·90	9,041·40	0·51	...
F 724 *	1939 Feb. 12·99	9,307·49	4·07	λ 4200 to λ 4650
F 725 *	13·03	9,307·53	4·11	...
F 728	16·96	9,311·46	2·57	...
F 730 *	20·95	9,315·45	1·09	...
F 731 *	20·99	9,315·49	1·13	...
F 736	27·02	9,321·52	1·69	...
F 740	Mar. 8·12	9,330·62	5·32	...
F 743	22·99	9,345·49	3·79	D lines
F 744	29·95	9,352·45	5·28	...
T 931	April 22·89	9,376·39	1·87	λ 3850 to $H\beta$
T 932	24·97	9,378·47	3·95	...
T 933 *	25·88	9,379·38	4·86	...
T 934 *	25·97	9,379·47	4·95	...
T 936	26·97	9,380·47	0·48	...
T 937 *	27·87	9,381·37	1·38	...
T 938 *	27·91	9,381·41	1·42	...
T 939	May 3·88	9,387·38	1·92	...
T 940	4·95	9,388·45	2·99	...
T 941	7·95	9,391·45	0·52	...
T 943	8·95	9,392·45	1·52	...
T 944	11·01	9,394·51	3·58	...

Note.—Each pair of plates marked with asterisks was taken on the same night.

*Mg*II. 4481 strong.
*Si*II. 4128 and 4131 strong.
*Ca*II. K and H are of moderate strength.
*Sc*II. 4247 and a few other lines weakly present.
*Ti*II. Well represented.
*V*II. Many lines present (11 out of 15).
*Cr*I. 4254 and 4290 present, 4275 possibly present in blend.
*Cr*II. All the laboratory lines present except a few predicted lines.
*Mn*II. Several coincidences. Probably present.
*Fe*I. Most of the stronger laboratory lines are weakly present.
*Fe*II. All laboratory lines in the region are strongly present.
*Sr*II. The two ultimate lines 4078 and 4215 present.
*Y*II. All the strong lines present.
*Zr*II. Many coincidences. Weakly present.
*Mo*II. 3 of the 4 laboratory lines in the region are present.
*Ce*II. About half of the strong laboratory lines are present; several stellar lines are not otherwise accounted for.
*Eu*II. All the strong lines present. See Table IV.
*Gd*II. Most strong laboratory lines are present. See Table VI.
*Tb*II. 17 of the 30 stronger laboratory lines are present. See Table VII.
*Dy*II. Nearly all the stronger laboratory lines are present. See Table V.

The presence of the following elements is rather doubtful :—

*La*II. 19 coincidences with stellar lines out of 41 stronger laboratory lines in the region.
*Pr*II. 13 out of 29.
*Nd*II. 11 out of 29.
*Sa*II. 37 out of 95. A good number of stellar lines are not otherwise accounted for, *e.g.* 4424, 4434, 4512, 4538, 4615.
*Eu*I. Slight traces of the three ultimate lines 4594, 4627 and 4662. The other neutral rare-earths are probably all absent, or are too weak to be detected.

For the following elements, the data available are not sufficient either to prove or to disprove their presence :—

*O*I. 4368 blended, 3947 absent.
*Ca*I. 4227 weak and blended, 4425 weakly present.
*Al*I. The only two lines 3944 and 3961·5 might contribute to the stellar lines 3944·80 and 3960·65.
*Si*I. The only line 3905 blended.
*Co*II. No strong laboratory line in the region.
*Ni*II. Only 4 weak lines in the region, only one of which coincides with a stellar line.
*Lu*II. Only line in the region. 4184 blended.
*Hf*II. Only line 4336·6 masked by *Hγ*.
*Pb*I. Only strong line 4058 present.
*Il*II. No data available for laboratory lines in this region.

*Er*II and *Tm*II. The only known reference for laboratory wave-lengths is Exner and Haschek's tables. There the lines due to ionized elements are not separated from that due to neutral elements.

*Yb*II. Only 3 weak lines in the region, all of which are present.

The following elements are probably absent :—

*He*I. 4471 and 4121 blended, 3965, 4026 and 4388 absent.

*Na*I. No trace of the D lines.

*K*I. The only two lines, 4044 and 4047, absent.

*K*II. 7 out of the 9 laboratory lines are absent.

*Ba*II. The ultimate line 4554 absent.

Miss Moore's multiplet table is the main source of laboratory wave-lengths For the rare-earths, the references are given in Table II, together with the number of strong laboratory lines and the number of coincidences with stellar lines.

TABLE II

Rare-earth Elements in α^2CVn

Elements	Strong Laboratory Lines in the Region			No. of Coincidences with Stellar Lines	Conclusion
	No.*	Criterion	Reference		
*La*II	41	Arc intensity $\geqslant$ 100	Miss Moore's *Multiplet Table*	19	?
*Ce*II	75	$\geqslant$ 100	A. S. King, *Ap. J.*, **68**, 201, 1928	39	Present?
*Pr*II	29	$\geqslant$ 100	King, *Ap. J.*, **68**, 222, 1928	13	?
*Nd*II	29	$\geqslant$ 100	King, *Ap. J.*, **78**, 9, 1933	11	?
*Il*II	...	No data available		...	?
*Sa*II	95	$\geqslant$ 100	W. Albertson, *Ap. J.*, **82**, 26, 1936	37	?
*Eu*II	7	$\geqslant$ 30	Albertson, *Phy. Rev.*, **45**, 499, 1934	7	Present
*Gd*II	77	$\geqslant$ 30	King, *Ap. J.*, **72**, 229, 1930	55	Present
*Tb*II	30	$\geqslant$ 30	King, *Ap. J.*, **72**, 236, 1930	17	Present?
*Dy*II	22	$\geqslant$ 30	King, *Ap. J.*, **72**, 244, 1930	21	Present
*Ho*II	2	$\geqslant$ 30	King, *Ap. J.*, **72**, 250, 1930	2	?
*Er*II †	24?	$\geqslant$ 8	Exner and Haschek	12	?
*Tm*II †	5?	$\geqslant$ 8	Exner and Haschek	4	?
*Yb*II	1	$\geqslant$ 30	King, *Ap. J.*, **74**, 331, 1931	1	?
*Lu*II	1	$\geqslant$ 30	King, *Ap. J.*, **74**, 336, 1931	1	?

* Not including those lines which will be masked by the strong hydrogen lines. Two laboratory lines which are close together are counted as one line.

† *Er*I and *Er*II are not separated from one another in Exner and Haschek's table. A portion of these 24 lines may be due to *Er*I. Same for Thulium.

A list of the stellar lines from λ 3900 to λ 4650 is given in Table III. Instead of giving the visual estimate of line intensity, we adopt the unit W/λ as a measure of intensity, W being the equivalent width. A numerical factor 10^5 is introduced to bring the ratio to a convenient size, so that apart from the Balmer lines, the strongest line in the spectrum would have approximately the intensity 10, while the weakest lines would have the intensity 1. Only integers are retained; 3·6 is written as 4. Relatively unimportant contributors are included in parentheses. If for any single line, all the contributors are included in parentheses, the implication is that the elements given are not enough to account for the intensity and the behaviour of the line.

Variation of Line Intensity

140 lines were chosen for the measurement of equivalent widths. These include all the strong lines, most unblended lines, and most lines which have previously been found by other observers to be variable. The results are given in the third column of Table III. "A" signifies variation in the same way as *Eu*II lines, "B" signifies variation in the opposite way. Group A lines weaken while Group B lines strengthen, and *vice versa*. "C" denotes constancy. When a query is put in the third column with nothing else in it, the line is either varying irregularly or its measured intensity is subjected to big accidental errors.

Of the 140 lines chosen, 64 (of which 9 are doubtful) are found to belong to Group A, 30 (8 doubtful) to Group B, and 41 (7 doubtful) found to be constant, and 5 to be "?". There is no positive evidence for the presence of any emission line.

TABLE III

Absorption Lines in the Spectrum of α^2CVn *

Wave-length	Intensity	Group	Elements
3900·53	3		*Ti*II 0·54 (*Al*II 0·66)
3902·34	2		*Gd*II 2·42
3902·97	2		*Fe*I 2·96, *V*II 3·26
3903·88	3		*Fe*I 3·92
3905·61	4–6	B	*Cr*II 5·66, *Si*I 5·53?
3907·23	4–2	A	*Eu*II 7·10 (*Ce*II 7·29)
3908·36	4–3	A	*Ce*II 8·41, 8·54
3913·63	4	C	*Ti*II 3·47
3916·48	3–1	A	*Gd*II 6·58 (*Zr*II 5·94, *V*II 6·41)
3918·64	2–4	B	*Ce*II 8·28
3920·38	3		*Fe*I 0·27, *Ce*II 9·81
3921·87	2		*Ce*II 1·73, *Sa*II 2·40
3923·29	4		*Ce*II 3·11, *Gd*II 3·25, *Fe*I 2·92, *Tb*II 2·74
3925·30	2	C?	*Tb*II 5·45
3927·83	2		*Fe*I 7·93, *Sa*II 8·28
3929·48	2		*La*II 9·22?
3930·35	7–3	A	*Eu*II 0·50 (*Fe*I 0·31)
3933·63	7–5	A	*Ca*II 3·68 (*Zr*II 4·12)

* *Note.*—*d* = double, *n* = nebulous, *b* = broad, *bl* = blend, *r* = faint component on red side, *v* = faint component on violet side.

TABLE III—*continued*

Wave-length	Intensity	Group	Elements
3935·10	1		*Tb*II 5·25, *Zr*II 4·79
3936·25	3		*Zr*II 6·06
3938·45	3		
3942·40	4–2	A	*Ce*II 2·15
3944·80	3		*Dy*II 4·69
3950·29	2		*Y*II 0·36
3952·46	2		*Ce*II 2·57, *Gd*II 2·01, *V*II 1·97
3954·38	3		
3957·73	4–1	A	*Gd*II 7·69, *Tb*II 7·97, 8·35, *Zr*II 8·22 (*Dy*II 7·80, *Cr*II 8·10)
3959·37	3–1	A	*Gd*II 9·44, 9·53
3960·65	2	C	*Ce*II 0·91
3968·40	*bl* with *Hε*	A	*Ca*II 8·49, *Dy*II 8·39
Hε	190–220	B	*H*I 3970·07
3981·90	2		*Tb*II 1·92, *Dy*II 1·93, *Y*II 2·60
3983·95	5–3	A	*Dy*II 3·66, 4·22 (*Ce*II 4·68)
3991·56	2		*Zr*II 1·12, *Dy*II 1·33, *Si*II 1·71
3996·44	2		*Dy*II 6·69 (*Gd*II 6·34, *V*II 7·11, *Al*II 5·86, 6·16, 6·38)
4000·24	3–1	A	*Dy*II 0·45
4002·53	3–5	B	*Tb*II 2·60, 2·20, *V*II 2·93
4005·30	2		*Tb*II 5·55, *Fe*I 5·26, *V*II 5·71
4009·08	2		*Gd*II 8·91
4012·61	4	C	*Ce*II 2·39, *Tb*II 2·84, *Ti*II 2·39
4022·09	2		*Fe*I 1·81
4024·09	3–5?	B?	*Tb*II 4·10, *Zr*II 4·45, *V*II 3·39?
4028·21	3		*Ce*II 8·41, *Ti*II 8·35
4029·84	3		*Zr*II 9·65
4032·56	2–4	B	*Tb*II 3·05 (*Dy*II 2·48)
4034·09	3		*Zr*II 4·10
4036·05	2		*V*II 5·71
4038·11	3		*Gd*II 7·90, 7·34?
4045·92	4–2	A	*Fe*I 5·83, *Zr*II 5·60, *Ho*II 5·43?
4046·49	2	?	*Ce*II 6·34
4049·15	6–3	A	*Gd*II 9·44, 9·90?, *Zr*II 8·67
4050·35	3–1	A	*Dy*II 0·58 (*Zr*II 0·33)
4054·28	4–2	A	*Ti*II 3·83, *Ce*II 3·51?, *Gd*II 3·31??
4055·30	3–1	A	*Dy*II 5·13
4058·02	2	C	*Pb*I 7·81?
4061·83	4–2	A	
4062·67	3–1	A	*Gd*II 2·61
4063·64	4–2	A	*Gd*II 3·45, *Fe*I 3·61, *Sa*II 3·54
4070·53	5–2	A	*Gd*II 0·29 (*Cr*II 0·99)
4071·80	2	C	*Fe*I 1·75, *Ce*II 1·85
4072·80	2	C	
4073·63	4–1	A	*Gd*II 3·78 (3·21), *Dy*II 3·11, *Ce*II 3·48
4075·80	3–4	B	*Ce*II 5·85, *Sa*II 5·84, *Si*II 5·45
4076·88	3	C	(*Si*II 6·78, *Cr*II 6·88)?
4077 78	5–3	A	*Sr*II 7·73, *Dy*II 7·97, *Gd*II 8·47?
4081·92	2	C?	*Ce*II 1·22?, *Sa*II 2·60?
4085·41	3–2?	A?	*Gd*II 5·60, *Ce*II 5·23
4087·58	2–1?	A?	*Fe*II 7·28 (*Cr*II 7·61, 7·80)
Hδ	220–230	B	*H*I 4101·74

TABLE III—*continued*

Wave-length	Intensity	Group	Elements
4111·02	3		*Dy*II 1·35, *Gd*II 1·45 (*Cr*II 1·00)
4117·17	3		
4118·64	2		*Ce*II 8·15, *Sa*II 8·55
4119·37	2	C?	
4121·33	1		*Ce*II 0·83
4122·77	3	C	*Fe*II 2·67
4124·90	2–1	A	*Dy*II 4·63
4128·09	8–11	B	*Si*II 8·05
4129·82	8–1	A	*Eu*II 9·73 (*Gd*II 0·35, *Dy*II 9·43)
4131·04	8–10	B	*Si*II 0·88 (*Ce*II 0·70, 1·10, *Gd*II 1·48)
4132·43	7–3	A	*Gd*II 2·28 (*Fe*I 2·07, *Cr*II 2·41)
4134·70	2		*Fe*I 4·69
4137·51	3		*Ce*II 7·64
4138·28	2		
4143·09	2		*Dy*II 3·10, *Fe*I 3·88??
4144·72	2–1	A	*Tb*II 4·47
4146·14	2		(*Cr*II 6·50?)
4149·23	1		*Zr*II 9·20
4156·04	2		*Zr*II 6·23, *Nd*II 6·08?
4161·68 *v*	3		*Zr*II 1·21 (*Ti*II 1·52)
4163·77 *d*	2		*Ti*II 3·66
4166·97 *d*	2		*Mg*I 7·28
4170·66	2		*Fe*I 0·91 (*Cr*II 0·64)
4171·92	4	C	*Ti*II 1·91
4173·72	3–4	B?	*Fe*II 3·47 (*Ti*II 3·55, 4·08)
4174·99	1		*Fe*I 4·92
4176·61	1		*Fe*I 6·58
4177·77	3		*Y*II 7·54 (*Sa*II 8·02, *V*II 8·39)
4179·24	3–5	B	*Fe*II 8·86 (*Cr*II 9·38, *Zr*II 9·82?)
4180·89	2	C	*Yb*II 0·83?
4182·24	2		*Fe*I 1·77
4184·48	2		*Gd*II 4·25, *Lu*II 4·26?
4187·49	3		*Fe*I 7·05, 7·86
4190·89	3	C	*Gd*II 1·06 (*Fe*I 1·44)
4193·99 *d*	2		
4196·03 *d*	2	C	*Fe*I 5·34, 6·22
4198·24 *n*	3		*Gd*II 7·68, *Fe*I 8·34, *Si*II 8·17
4200·82	2–5	B	*Tb*II 1·00, *Fe*I 0·93, *Mn*II 0·25?
4204·64	2		*Fe*I 2·04, *Ce*II 2·94, *V*II 2·35 (*Al*II 2·4)
4205·09	9–2	A	*Eu*II 5·05 (*Gd*II 4·84, *V*II 5·08)
4207·84	4–2	A	(*Cr*II 7·34?)
4210·27	1		*Fe*I 0·34, 0·40, *V*II 9·83, *Sa*II 0·35
4212·31	3–1?	A?	*Gd*II 2·01 (*Zr*II 1·89)
4213·71	3–1	A	*Tb*II 3·56, *Ce*II 4·04
4215·47	4–3	A	*Sr*II 5·52, *Gd*II 4·97
4217·94 *n*	3–1?	A?	*La*II 7·56?, *Gd*II 7·15?
4219·81	1		*Fe*I 9·36
4222·86	2		*Ce*II 2·60
4224·99	2		*Sa*II 5·33, *V*II 5·22
4227·45	3		*Ce*II 7·75, *Fe*I 7·44, *Al*II 6·81, 7·49, 7·48, *Ca*I 6·74?
4229·84	3		*Sa*II 9·70
4233·23	4–7	B	*Fe*II 3·17 (*Cr*II 3·25)

TABLE III—*continued*

Wave-length	Intensity	Group	Elements
4235·65 *r*	2		*Fe*I 5·95, *Y*II 5·74
4238·43 *n*	1		*Gd*II 8·77
4240·16	1		*Al*II 0·75, *Ce*II 9·91
4241·22	2–1?	A?	
4242·53	2–4	B	*Cr*II 2·38 (*Mn*II 2·38)
4246·49	2–3	B?	*Sc*II 6·84
4250·59	3	C	*Fe*I 0·13, 0·80, *Mo*II 0·71
4251·78	3–1	A	*Gd*II 1·76 (*Mn*II 1·77)
4253·28 *n*	2		*Gd*II 3·36, 3·62 (*Mn*II 3·02)
4254·72	2	C	*Cr*I 4·35
4256·21	3	C	*Sa*II 6·39
4258·23	2–4	B	*Fe*II 8·17, *Zr*II 8·05
4259·38	2		*Mn*II 9·26
4260·81	1		*Fe*I 0·49
4262·13	3–4?	B?	*Gd*II 2·09, *Sa*II 2·68, *Cr*II 1·93
4264·28 *n*	2		(*Fe*I 4·22, 4·74), *La*II 3·61?
4267·09	2–1?	A?	*C*II 7·02? 7·27?
4269·33	2–3?	B?	*Cr*II 9·29, *Gd*II 8·73
4270·59	4–2	A	*Ce*II 0·19, 0·72
4271·99	3	C	*Fe*I 1·78
4273·70	3	C	*Fe*II 3·33
4275·77	3		*Cr*II 5·56 (*Cr*I 4·81?)
4278·08	2	C	*Tb*II 8·54
4280·44	3		*Gd*II 0·50, *Sa*II 0·79
4282·51	3		*Mn*II 2·50, *Fe*I 2·41
4284·47	3		*Cr*II 4·23
4285·82 *d*	3		*Sa*II 5·50, 6·64?
4288·23	4		*Ti*II 7·89
4290·13	5–3	A	*Ti*II 0·23, *Ce*II 9·94 (*Cr*I 9·73)
4292·98	2–1	A	*Zr*II 3·13
4294·05	2		*Ti*II 4·10 (*Fe*I 4·10)
4296·70	5–3	A	*Gd*II 6·04 (6·34, 7·15), *Fe*II 6·58, *Ce*II 6·68
4300·25	3–2	A	*Ti*II 0·05
4301·79	3–1	A	*Ti*II 1·93
4303·29	3–5	B	*Fe*II 3·18
4307·86	3	C	*Ti*II 7·91 (*Fe*I 7·91)
4308·24	3		*Dy*II 8·62
4312·89	3–4?	B?	*Ti*II 2·88
4314·72	3	C?	*Ti*II 4·98 (*Sc*II 4·09, *Fe*I 5·10)
4317·33	2		*Zr*II 7·32, *Ti*II 6·80
4319·65	2		*Cr*I 9·65
4321·12	2	C	*Gd*II 1·11, *Sc*II 0·75, *Ti*II 0·96
4325·75	3–4	B	*Fe*I 5·78, *Tb*II 5·82, *Gd*II 5·57
4330·55	5–2	A	*Gd*II 0·58 (*Ti*II 0·25, 0·71)
Hγ	220–250	B	*H*I 4340·47
4351·99	4		*Fe*II 1·77 (*Mg*I 1·92, *Mn*II 1·77)
4355·15	4–1	A	*Eu*II 5·09 (*Sc*II 4·60)
4356·77	1		*Al*II 6·71, 6·81
4359·76	1		*Zr*II 9·75, *Mn*II 9·26
4361·81	3–1	A	*Sa*II 2·04
4363·68 *n*	3–2	A	*Ce*II 4·66?
4367·87	3–2	A	*Ti*II 7·68, *Sa*II 8·03, *O*I 8·30?
4369·71	3	C	*Gd*II 9·77, *Fe*II 9·41

TABLE III—*continued*

Wave-length	Intensity	Group	Elements
4372·16	2		
4374·81	2		*Y*II 4·95 (*Sc*II 4·47, *Ti*II 4·82, *Sa*II 4·97)
4377·50	1		*Mo*II 7·77
4384·13 *n*	2		*Fe*I 3·56, *Gd*II 3·16?
4385·54	2–4	B	*Fe*II 5·39
4386·79	3–2	A	*Ti*II 6·85
4391·24	2		*Ce*II 1·66, *Gd*II 0·95, *Sa*II 0·86
4393·80	1		*Ti*II 4·07
4395·76	4		*Ti*II 5·04 (5·85)
4397·72	2		*Gd*II 7·50, *Y*II 8·02 (*Ti*II 8·30)
4399·72	3–2?	A?	*Ti*II 9·78
4401·58	2–1	A	(*Fe*I 1·30, 1·45)
4403·24	2	C	*Sa*II 3·36, *Zr*II 3·38
4404·81	3	C	*Fe*I 4·76
4406·87	2–1	A	*Gd*II 6·68
4407·86	2–1	A	*Gd*II 8·25 (*Ti*II 7·65)
4409·66	5–3	A	*Dy*II 9·38, *Sa*II 9·33
4411·32	2		*Ti*II 1·08
4413·94 *d*	3		(*Zr*II 4·56)
4416·90	3	C	*Fe*II 6·82
4417·81	3		*Ti*II 7·72
4419·00	3	C	*Gd*II 9·03, *Ce*II 8·78
4422·47	3–1	A	*Y*II 2·58 (*Ti*II 1·95)
4424·42	2–1	A	*Sa*II 4·34
4425·56	1		*Ca*I 5·43?
4427·55	2		*Fe*I 7·32
4431·49 *b*	4		*Fe*I 0·62, *Sc*II 1·37, *Ti*II 2·09?
4434·04	4–2	A	*Sa*II 3·88, 4·32
4435·57	4–2	A	*Eu*II 5·58
4443·74	5		*Ti*II 3·81 (*Zr*II 3·00?)
4447·79	6–3	A	(*Fe*I 7·73, *Al*II 7·8)
4450·45	3		*Ti*II 0·49, *Dy*II 9·70
4455·37	2		*Zr*II 4·80
4457·19	2		*Zr*II 7·44
4461·86	4?	?	*Fe*I 1·66, *Zr*II 1·21
4468·67	3		*Ti*II 8·50
4471·28	4–2?	A?	*Ce*II 1·24, *Gd*II 1·28, *He*I 1·48?
4473·27	3		*Fe*II 2·93, *Sa*II 3·01
4481·32	8–10	B	*Mg*II 1·14, 1·34 (*Gd*II 1·06)
4483·87	3–1	A	*Gd*II 3·32, *Ce*II 3·90
4489·64	5?	C?	*Fe*II 9·19
4491·55	3	C?	*Fe*II 1·41
4493·52	3	C	*Ti*II 3·53
4501·17	3		*Ti*II 1·28
4502·96	2		
4507·06	2		*Gd*II 6·34? (*Cr*II 7·23)
4508·51	1		*Fe*II 8·29
4512·01	1–3?	B?	*Sa*II 1·83
4514·36	4		*Gd*II 4·50
4515·45	6	C?	*Fe*II 5·35
4520·34	3–5	B	*Fe*II 0·23
4522·99	5	C	*Fe*II 2·64, *Eu*II 2·59, *Gd*II 2·82, *Ce*II 3·08, *Sa*II 3·04, *La*II 2·37?

TABLE III—*continued*

Wave-length	Intensity	Group	Elements
4524·94	2		*Ti*II 4·69
4530·47	2		*Fe*I 8·63, *Ti*II 9·49
4534·00	6–5?	A?	*Ti*II 3·97, *Fe*II 4·17
4536·04	2	C	*Cr*I 5·72
4537·89	1		*Sa*II 7·95
4540·11	3	C	*Ce*II 9·75
4541·54	4	?	*Fe*II 1·52
4545·01	3		(*Ti*II 5·14, *Cr*II 4·69)
4546·68	2		*Cr*I 5·96?
4549·62	7–9	B	*Fe*II 9·48, *Ti*II 9·64
4556·27	4		*Fe*II 5·89 (*Cr*II 4·99)
4558·74	4–6	B	*Cr*II 8·65 (*Gd*II 8·07?)
4563·81	4–2	A	*Ti*II 3·77
4566·45	3		*Sa*II 6·21
4569·24	2	C	
4572·22	4		*Ti*II 1·98, *Ce*II 2·28
4576·48	3	?	*Fe*II 6·34
4580·00	3	?	*La*II 0·08?
4582·90	4		*Fe*II 2·84, *Gd*II 2·49
4584·24	7–5	A	*Fe*II 3·84 (*Sa*II 4·83?)
4588·34	3–5	B	*Cr*II 8·21 (*Al*II 8·19)
4589·94	3	C	*Ti*II 9·96, *Cr*II 9·96, *Al*II 9·75
4592·23	4	C	*Cr*II 2·06, *Sa*II 1·82
4594·06	2	C	*Ce*II 3·94, *Sa*II 3·54, *Eu*I 4·03?
4596·12	3		*Fe*II 5·69
4598·42	2		*Ge*II 7·91
4611·29	1		*Fe*I 1·29
4615·69	1		*Sa*II 5·69, 5·44
4616·94	4		*Cr*II 6·63
4618·96	6		*Cr*II 8·79
4621·81	7–4?	A	
4623·37	1		
4625·22	2		*Fe*I 5·05
4627·31	1		*Eu*I 7·22?
4629·85	3		*Fe*II 9·34, *Ti*II 9·34
4632·24	1		(*Al*II 1·5, 3·2)
4634·16	4		*Cr*II 4·08
4640·79	1		*Al*II 0·36, 0·37
4657·09	2		*Fe*II 6·98
4658·83			

In the second column of Table III, two numbers are put down for the intensity of those lines which are found to be variable, the first being the intensity at *Eu*II maximum, and the second that at *Eu*II minimum. For those lines which have not been chosen for detailed study of intensity variation, the number given in that column indicates the intensity at *Eu*II maximum as measured from those spectrograms which were chosen for wave-length measurement.

Remarks on a few important elements are given in the following paragraphs :—

*Eu*II. There seems to be no question about the presence of europium

in this star. All the strong laboratory lines of *Eu*II in the investigated region are present except 3972 which is masked by *H*ϵ. All the lines except 4523 behave in the same manner. The influence due to the rare-earth contributors to the stellar line 4523 is probably counterbalanced by that due to *Fe*II, therefore the line is constant. No other line in the whole spectrum varies as much during each cycle as the two ultimate lines of *Eu*II, 4130 and 4205. Their unusual range of variation might be partly accounted for by their being blended with *Gd*II and *Dy*II. Since other *Gd*II and *Dy*II lines behave in the same way as *Eu*II, these contributors to the lines 4130 and 4205 reinforce one another at maximum and decline together at minimum.

In Table IV we list the *Eu*II lines together with intensity, group, multiplet, excitation potentials, and other contributors to the same line. As usual, the relatively unimportant contributors are included in parentheses. The laboratory wave-length, intensity, and temperature class are taken from A. S. King's recent paper * on *Eu*II lines. The intensity scale adopted in this paper is about ten times larger than in his former paper †

TABLE IV

*Eu*II *Lines*

Wave-length		Intensity		Group	Multiplet	E.P.		Other Contributors to Stellar Lines
Lab.	Star	Lab.	Star			Low	High	
3907·10	7·23	3000 II	4–2	A	$a^7S_3^0 - z^7P_2$	0·21	3·36	(*Ce*II)
3930·50	0·35	4000 II	7–3	A	$a^7S_3^0 - z^7P_3$	0·21	3·35	(*Fe*I)
3971·98	...	4000 II	*bl* with *H*ϵ		$a^7S_3^0 - z^7P_4$	0·21	3·31	*H*ϵ, etc.
4129·73	9·82	5000 II	8–1	A	$a^9S_4^0 - z^9P_4$	0	2·99	(*Gd*II, *Dy*II)
4205·05	5·09	6000 II	9–2	A	$a^9S_4^0 - z^9P_3$	0	2·93	(*Gd*II, *V*II)
4355·09	5·15	300 V	4–1	A	$z^9P_5 - e^9S_4^0$	3·23	6·06	(*Sc*II)
4435·58	5·57	3000 II	4–2	A	$a^7S_3^0 - z^9P_4$	0·21	2·99	...
4522·59	2·99	2000 II	5	C	$a^7S_3^0 - z^9P_3$	0·21	2·93	*Fe*II, *Gd*II, *Ce*II, *Sa*II

and in the paper by Albertson ‡, in order to enable the numerous faint lines to have integral intensity. The multiplet designation and E.P. are from Albertson. It is to be noted that the line 4355, with much higher E.P. than the other lines, varies in the same way as the others.

The equivalent widths of the lines 4130, 4205 and 4355 are plotted against phase in fig. 1. It is seen that maximum line strength occurs at the phase 1·2 days approximately. Therefore there is either some error in Farnsworth's formula for *Eu*II maximum, most probably in the period

* *Ap. J.*, **89**, 377, 1939.
† *Ap. J.*, **72**, 221, 1930.
‡ *Phys. Rev.*, **45**, 499, 1934.

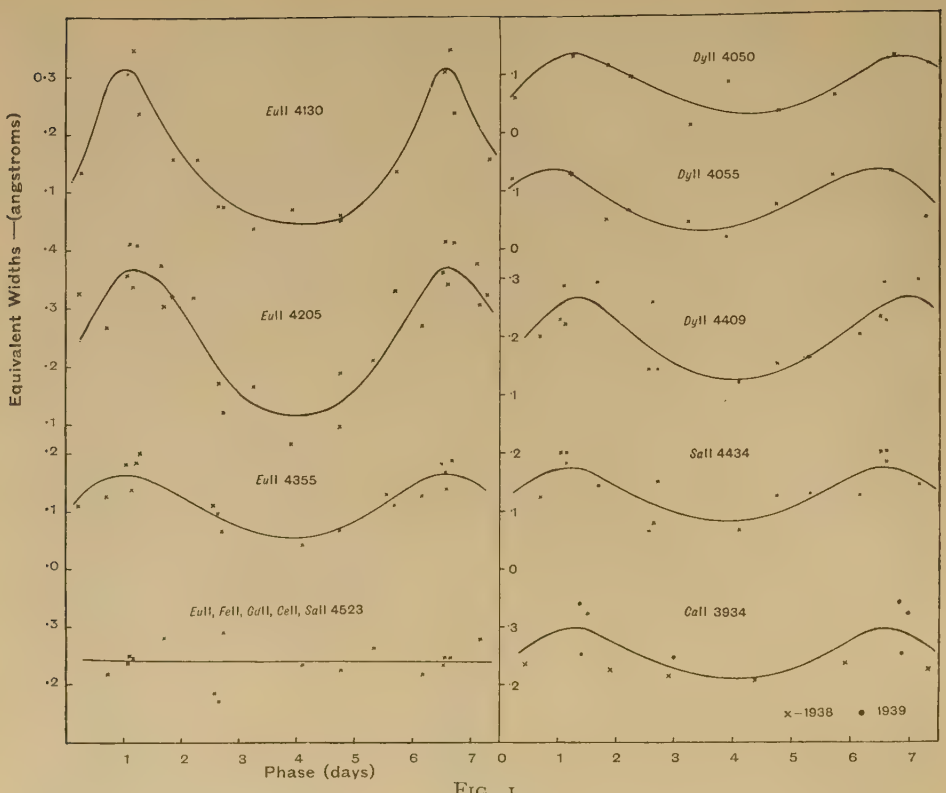
Equivalent Widths —(angstroms)
EuII 4130
EuII 4205
EuII 4355
EuII, FeII, GdII, CeII, ScII 4523
DyII 4050
DyII 4055
DyII 4409
ScII 4434
CaII 3934
x–1938 • 1939
Phase (days)

FIG. 1

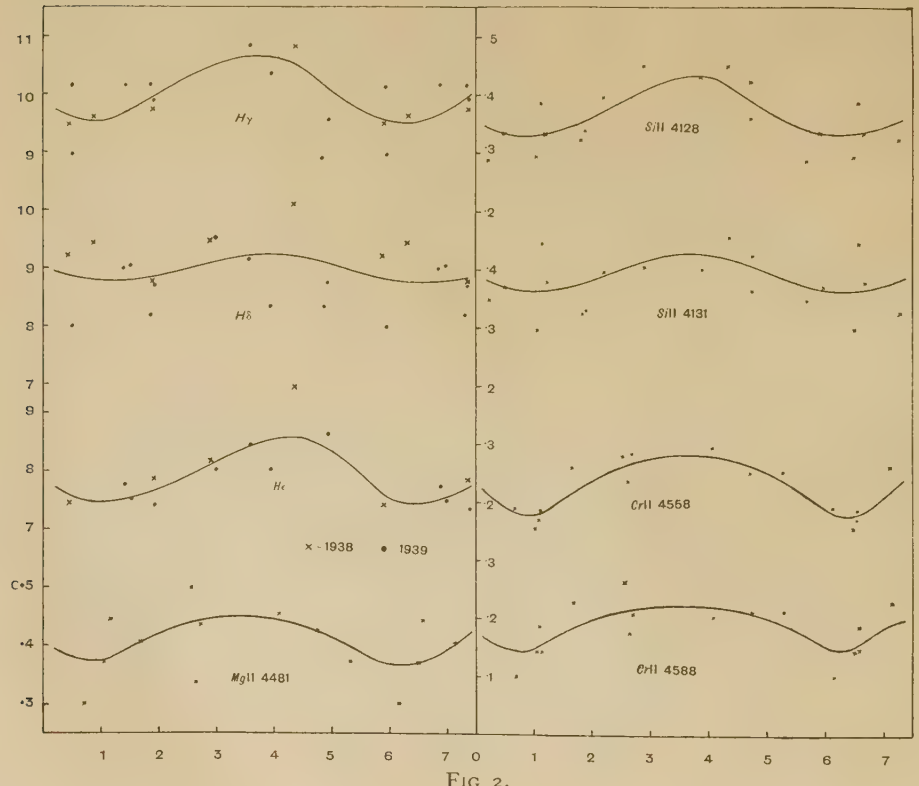
Hγ
Hδ
Hε
MgII 4481
SiII 4128
SiII 4131
CrII 4558
CrII 4588
x - 1938 • 1939

FIG 2.

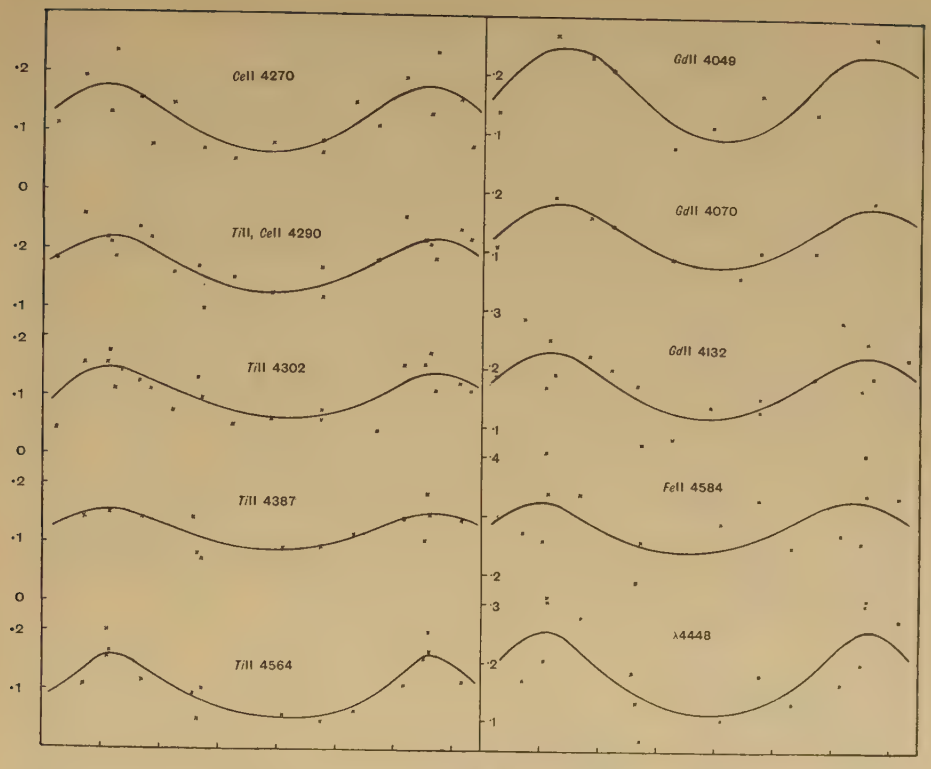
CeII 4270
TiII, CeII 4290
TiII 4302
TiII 4387
TiII 4564
GdII 4049
GdII 4070
GdII 4132
FeII 4584
λ4448

FIG. 3

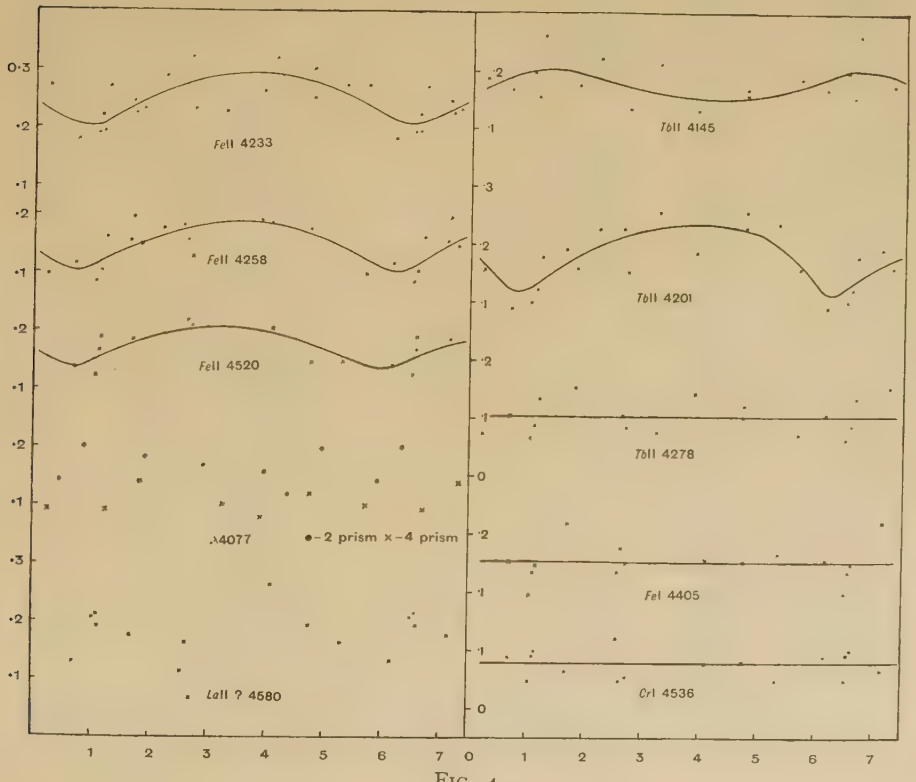
FeII 4233
FeII 4258
FeII 4520
λ4077
● – 2 prism × – 4 prism
LaII ? 4580
TbII 4145
TbII 4201
TbII 4278
FeI 4405
CrI 4536

FIG. 4

given, which accumulates to this difference of 1·2 days; or there may be a secular decrease in this period. All the points for these four lines are obtained from four-prism plates. There is a systematic difference between the equivalent widths measured from the two-prism plates and that from the four-prism plates; those from the two-prism plates are in general larger. We shall avoid combining the two sets whenever possible. Data for the constant line 4523 are also plotted in fig. 1.

*Dy*II. The presence of *Dy*II in the star also seems to be unquestionable when we look at Table V. λ 3931·53 was not measured on the plate, but on all the microphotometer tracings a depression was noticed between the two stronger lines *Eu*II 3930 and *Ca*II 3933. Very probably *Dy*II 3931 is one of those lines which combine to form the depression. All the *Dy*II lines chosen for intensity measurement except λ 4033 are found to belong to Group A, *i.e.* they behave in the same manner as *Eu*II. This fact further confirms the correctness of the identification of the stellar lines with *Dy*II. λ 4033 is mainly due to *Tb*II. The equivalent widths of three *Dy*II lines are plotted in fig. 1.

TABLE V

*Dy*II *Lines*

Wave-length		Intensity		Group	Contributors to Stellar Lines
Lab.	Star	Lab.	Star		
3872·14	2·63	300 IV	4?	A	*Dy*II
3898·54	8·76	300 IV	4?	A	*Dy*II (*Tb*II)
3931·53	—	150 IV	?		
3944·69	4·80	600 IV	3		*Dy*II
3957·80	7·73	30 V	4–1	A	*Gd*II, *Tb*II, *Zr*II (*Dy*II, *Cr*II)
3968·36		1000 III			Blended with *H*ϵ
3978·56		150 IV			... ... *H*ϵ
3981·93	1·90	75 V	2		*Tb*II, *Dy*II, *Y*II
3983·66	3·95	100 IV	5–3	A	*Dy*II (*Ce*II)
3984·22	...	60 V	...	...	...
3991·33	1·56	30 V	2		*Zr*II, *Dy*II, *Si*II
3996·69	6·44	200 IV	2		*Dy*II (*Gd*II, *V*II?, *Al*III)
4000·45	0·24	600 III	3–1	A	*Dy*II
4032·48	2·56	30 V	2–4	B	*Tb*II (*Dy*II)
4050·58	0·35	150 IV	3–1	A	*Dy*II (*Zr*II)
4055·13	5·30	30 V	3–1	A	*Dy*II
4073·11	3·63	200 IV	4–1	A	*Gd*II, *Dy*II, *Ce*II
4077·97	7·78	600 III	5–3	A	*Sr*II, *Dy*II, *Gd*II?
4103·31		500 IV			Blended with *H*δ
4111·35	1·02	150 IV	3		*Dy*II, *Gd*II (*Cr*II)
4124·63	4·90	30 V	2–1	A	*Dy*II
4129·43	9·82	100 IV	8–1	A	*Eu*II (*Gd*II, *Dy*II)
4143·10	3·09	300 IV	2		*Dy*II, *Fe*I??
4308·62	8·24	100 IV	3		*Dy*II
4409·38	9·66	40 IV	5–3	A	*Dy*II, *Sa*II
4449·70	0·45	60 IV			*Ti*II, *Dy*II

*Gd*II. *Gd*II lines are listed in Table VI. In the second and the fourth columns, three dots mean that the line is blended with the line above to

form the single stellar line observed. A dash means that the line is absent in star, and a blank space means that the line is masked by one of the strong Balmer lines. Less than one-third of the laboratory lines are absent in the star, and most of these absent lines are of intensity 100 or less. Of the lines chosen for intensity measurement, the great majority are found to belong to Group A. Those lines which have no entry in the fifth column were not chosen for the study of intensity variation. The lines which belong to Group B are easily seen to be mainly due to something else, *Si*II, *Mg*II, or *Cr*II. The excitation potentials given in Table VI are from unpublished data on *Gd*II which Dr. Albertson has kindly sent to the writer. The lines whose E.P. are not given have not yet been classified.

TABLE VI

*Gd*II *Lines*

Wave-length		Intensity		Group	E.P.		Contributors to Stellar Lines
Lab.	Star	Lab.	Star		Low	High	
3902·42	2·34	150 IV	2				*Gd*II
3916·58	6·48	300 IV	3–1	A	0·55	3·70	*Gd*II (*Zr*II, *V*II)
3923·25	3·29	30 IV	4				*Ce*II, *Gd*II, *Fe*I, *Tb*II
3952·01	2·46	40 V	2				*Ce*II, *Gd*II, *V*II
3957·69	7·73	150 IV	4–1	A	0·60	3·71	*Gd*II, *Tb*II, *Zr*II, etc.
3959·44	9·37	30 V	3–1	A	0·55	3·70	*Gd*II
3959·53	...	50 V	...	...			...
3971·77		40 V					Blended with *He*
3974·06		40 IV			0·49	3·58	...
3987·24	—	60 IV	—				
3994·19	—	40 V	—				
3996·34	6·44	40 V	2				*Dy*II (*Gd*II, *V*II, *Al*II)
4001·20	—	30 IV	—				
4008·91	9·08	30 V	2				*Gd*II
4037·34	8·11	200 IV	3		0·66	3·71	*Gd*II?
4037·90	...	125 IV	...		0·55	3·61	*Gd*II
4049·44	9·15	150 IV	6–3	A	0·66	3·70	*Gd*II, *Zr*II
4049·90	...	200 IV	...	...			*Gd*II?
4053·31	—	100 V	—				
4062·61	2·67	50 V	3–1	A			*Gd*II
4063·45	3·64	150 IV	4–2	A			*Gd*II, *Fe*I
4070·29	0·53	40 IV	5–2	A	0·55	3·58	*Gd*II (*Cr*II)
4073·21	3·63	40 IV	4–1	A			*Gd*II, *Dy*II, *Ce*II
4073·78	...	200 IV	...	...			...
4078·47	7·78	200 IV	5–3	A	0·60	3·62	*Sr*II, *Dy*II, *Gd*II?
4085·60	5·41	200 IV	3–2?	A?			*Gd*II, *Ce*II
4094·48		30 IV					Blended with *Hδ*
4098·64		300 IV					...
4098·90		80 IV			0·60	3·61	...
4111·45	1·02	60 V	3				*Dy*II, *Gd*II (*Cr*II)
4130·35	9·82	300 V	8–1	A	0·60	3·58	*Eu*II (*Gd*II, *Dy*II)
4131·48	1·04	40 V	8–10	B			*Si*II (*Ce*II, *Gd*II)
4132·28	2·43	200 IV	7–3	A	0·60	3·58	*Gd*II (*Fe*I, *Cr*II)
4162·72	3·77 *d*	60 V	2		0·49	3·45	*Ti*II (*Gd*II?)
4184·25	4·48	300 IV	2		0·49	3·44	*Gd*II, *Lu*II?
4191·06	0·89	200 IV	3	C			*Gd*II (*Fe*I)

TABLE VI—*continued*

Wave-length		Intensity		Group	E.P.		Contributors to Stellar Lines
Lab.	Star	Lab.	Star		Low	High	
4197·68	8·24 *n*	80 IV	3				*Gd*II, *Fe*I, *Si*II
4204·84	5·09	100 V	9–2	A			*Eu*II (*Gd*II, *V*II)
4212·01	2·31	200 IV	3–1	A?			*Gd*II (*Zr*II)
4214·97	5·47	150 IV	4–3	A			*Sr*II, *Gd*II
4217·15	—	100 IV	—		0·66	3·58	
4238·77	8·43	80 V	1				*Gd*II
4251·76	1·78	300 IV	3–1	A	0·38	3·28	*Gd*II (*Mn*II)
4253·36	3·28	150 IV	2		0·55	3·45	*Gd*II (*Mn*II)
4253·62	...	150 V	...				...
4262·09	2·13	250 V	3–4?	B?			*Gd*II, *Sa*II, *Cr*II
4268·73	9·33	30 V	2–3	B			*Cr*II, *Gd*II
4280·50	0·44	200 IV	3				*Gd*II, *Sa*II
4296·04	6·70	150 IV	5–3	A			*Gd*II, *Fe*II, *Ce*II
4296·30	...	40 V	...	...			...
4297·15	...	40 V	...	...			...
4304·90	—	30 V	—				
4310·95	—	30 V	—		0·49	3·35	
4316·05	—	150 IV	—		0·66	3·52	
4321·11	1·12	60 V	2	C	0·60	3·45	*Gd*II, *Sc*II, *Ti*II
4325·57	5·75	30 V	3–4	B			*Fe*I, *Tb*II, *Gd*II
4330·38	0·55	100 IV	5–2	A			*Gd*II (*Ti*II)
4341·24		150 IV					Blended with *Hγ*
4342·18		300 IV			0·60	3·44	...
4347·25		40 V					...
4360·90	—	40 IV	—				
4369·77	9·71	80 IV	3	C	0·38	3·20	*Gd*II, *Fe*II
4383·16	—	30 V	—				
4387·63	—	100 IV	—				
4390·95	1·24	80 IV	2				*Ce*II, *Gd*II, *Sa*II
4397·50	7·72	60 V	2				*Gd*II, *Y*II (*Ti*II)
4406·68	6·87	60 IV	2–1	A			*Gd*II
4408·25	7·86	80 IV	2–1	A	0·55	3·35	*Gd*II (*Ti*II)
4419·03	9·00	150 IV	3	C	0·49	3·28	*Gd*II, *Ce*II
4421·21	—	30 V	—				
4436·23	5·57	40 IV	4–2	A			*Eu*II (*Gd*II?)
4438·26	—	60 IV	—		0·66	3·44	
4446·46	—	30 IV	—				
4466·55	—	125 V	—				
4471·28	1·28	60 V	4–2?	A?			*Ce*II, *Gd*II, *He*I?
4478·79	—	80 IV	—		0·60	3·35	
4481·06	1·32	100 IV	8–10	B	0·60	3·35	*Mg*II (*Gd*II)
4483·32	3·87	80 IV	3–1	A			*Gd*II, *Ce*II
4498·26	—	60 IV	—				
4506·34	7·06	60 IV	2				*Gd*II? (*Cr*II)
4514·50	4·36	40 V	4				*Gd*II
4522·82	2·99	80 V	5	C			*Fe*II, *Eu*II, *Gd*II, etc.
4558·07	8·74	40 IV	4–6	B			*Cr*II (*Gd*II?)
4582·49	2·90	40 V	4				*Fe*II, *Gd*II
4596·98	—	60 IV	—				
4597·91	8·42	100 IV	2		0·60	3·28	*Gd*II
4601·03	—	100 IV	—		0·55	3·23	

One of the most marked variable lines in the spectrum is λ 4132. Situated in the most accessible part of the spectrum this line forms with the *Si*II doublet and *Eu*II 4130 an interesting group of four. The group is reduced to a doublet periodically, so the line has been known for some time to be one that belongs to the europium group. Most authors left it unidentified. Morgan * put down *V*I, *Fe*I, *Mn*II, *Gd*II, *Cr*II as tentative identification. We now see that the line is mainly due to *Gd*II. *Fe*I and *Cr*II contribute only a little to it. Three unblended *Gd*II lines are plotted in fig. 3.

*Tb*II. We now come to another ionized rare-earth element, *Tb*II, which presents more difficulties than *Eu*II, *Dy*II, or *Gd*II. Table VII is constructed in the same fashion as the previous two tables. Only 60 per cent. of the stronger laboratory lines are present. The line λ 3899 was measured on the plates T 934 and T 936. λ 3896 was not measured on these two plates, nor on the plate T 931, but on some tracings it appears as a faint line on the red wing of $H\zeta$. The absence of the two strong laboratory lines 3939·6 and 3946·9 is rather surprising. The former was, however, given in Kiess's paper, but it was observed on only one plate.

TABLE VII

*Tb*II

Wave-length		Intensity		Group	Contributors to Stellar Lines
Lab.	Star	Lab.	Star		
3874·18		200 IV			Masked by $H\zeta$
3896·04	?	25 V	?		
3896·60	...	25 V	...		
3899·19	8·76	200 IV	4?	A	*Dy*II (*Tb*II)
3919·54	—	40 IV	—		
3922·74	3·29	50 V	4		*Ce*II, *Gd*II, *Fe*I, *Tb*II
3925·45	5·30	150 V	2	C?	*Tb*II
3935·25	5·10	50 IV	1		*Tb*II, *Zr*II
3939·60	—	200 IV	—		
3946·87	—	150 IV	—		
3957·97	7·73	40 V	4–1	A	*Gd*II, *Tb*II, *Zr*II, etc.
3958·35	...	60 V	...	...	...
3970·19					Blended with $H\epsilon$
3976·86					...
3981·92	1·90	150 V	2		*Tb*II, *Dy*II, *V*II
4002·20	2·53	50 V	3–5	B	*Tb*II, *V*II
4002·60	...	100 IV	...	...	...
4005·55	5·30	200 IV	2		*Tb*II, *Fe*I, *V*II
4012·84	2·61	40 IV	4	C	*Ce*II, *Tb*II, *Ti*II
4020·47	—	30 V	—		
4024·10	4·09	30 V	3–5?	B?	*Tb*II, *Zr*II, *V*II?
4031·65	—	50 V	—		
4033·05	2·56	200 IV	2–4	B	*Tb*II (*Dy*II)
4051·87	—	30 V	—		
4060·86	—	40 V	—		
4066·21	—	30 V	—		

* *Pub. Yerkes Obs.*, 7, part 3, 1935.

TABLE VII—*continued*

Wave-length		Intensity		Group	Contributors to Stellar Lines
Lab.	Star	Lab.	Star		
4144·47	4·72	100 IV	2–1	A	*Tb*II
4201·00	0·82	30 V	2–5	B	(*Tb*II, *Fe*I, *Mn*II?)
4213·50	3·71	30 V	3–1	A	*Tb*II, *Ce*II
4226·45	—	60 V	—		
4278·54	8·08	200 V	2	C	*Tb*II
4325·82	5·75	60 V	3–4	B	*Fe*I, *Tb*II, *Gd*II
4342·5		30 V			Blended with *Hγ*
4353·19	—	50 V	—		
4578·62	—	30 V	—		
4641·97	—	30 V	—		
4645·26	—	50 V	—		

In order to compare the present results with that obtained by earlier observers, all the terbium lines contained in Markov's paper are listed in Table VIII, together with the corresponding laboratory lines of terbium and the present results. BB means that the line definitely belongs to Group B. In the laboratory section, the wave-length, the intensity in the arc and in the furnace, and the temperature class are given. Lines marked E are due to *Tb*II, and those marked A due to *Tb*I. From the table we notice a general agreement in the assignment of the lines to groups, but agreement in the identification is not so good. The author finds it difficult to identify the line 4534 with the weak *Tb* lines 4·13 and 4·29 of intensity 5, when some other *Tb* lines of intensity 150 are missing, and when other *Ti*II and *Fe*II lines are pretty strong. *Tb*I is most probably absent, because *Eu*I is almost absent, and many other stronger *Tb*I lines are missing. Any coincidence with *Tb*I lines is to be regarded as accidental. A multiplet table of *Tb*II lines will be found very helpful in our identification, but unfortunately among the ionized rare-earth elements, only *Eu*II and *Sa*II have their multiplets worked out, while *Ce*II * and *Gd*II are only partly done.

λ 4201 is one of the most notable members of Group B. The weak *Tb*II line 4201·00 and the weak *Fe*I line 0·92 do not seem to be enough to account for the intensity and the behaviour of the stellar line.† Besides 4201 and 4326, all other unblended *Fe*I lines in the spectrum are found to be weak and constant. λ 4278 is a strong laboratory line of *Tb*II. It was formerly observed to be a Group B line, but is now found to be constant. Three *Tb*II lines are plotted in fig. 4.

As the matter stands we can only say that *Tb*II is probably present in the star. A few lines of *Tb*II are found to belong to Group B. The material now available is not adequate to show whether *Tb*II is responsible for the variation of these lines.

*Ce*II. More than one-half of the stronger laboratory lines of *Ce*II are

* Albertson and Harrison, *Phys. Rev.*, **52**, 1029, 1937.

† 4201 is, in fact, one of the strongest lines usually left unidentified in early type spectra.

TABLE VIII

Tb Lines found by Earlier Observers compared with Present Results

Markov			Laboratory			Present Results		
3848·90	*Tb*	B	8·90	100–6	IVE	Out of spectral range		
3942·35	*Tb*	B	2·40	15–	VE	2·40	*Ce*II	A
3954·21	*Tb*	B	4·04	10–6	III	4·38	?	?
			4·13	5–8	III			
			4·51	1–2	IIIA			
			4·77	1–	VE			
3977·0	*Tb*	B	6·86	250–15	IVE	Masked by *Hε*		
4002·73	*Tb*	BB	2·53	50–	VE	2·53	*Tb*II, *V*II	B
			2·60	100–2	IVE			
4033·20	*Tb*	B	3·05	200–6	IVE	2·56	*Tb*II (*Dy*II)	B
4172·19	*Tb*	C	1·78	12–15	III	1·92	*Ti*II	C
			2·55	15–2	III			
4201·16	*Tb*	BB	1·00	30–2	VE	0·82	*Tb*II, *Fe*I	B
4232·98	*Tb, Fe*	BB	2·20	20–	VE	3·23	*Fe*II (*Cr*II)	B
			2·84	25–20	III			
4242·5	*Tb*	BB	2·27	8–6	III	2·53	*Cr*II (*Mn*II)	B
			2·57	12–	VE			
4278·70	*Tb*	B	8·54	200–	VE	8·08	*Tb*II	C
4326	*Tb*	BB	5·82	60–4	VE	5·75	*Fe*I, *Tb*II, *Gd*II	B
4534·30	*Tb*	C	4·13	5–1	III	4·00	*Ti*II, *Fe*II	A?
			4·29	1–3	IIIA			

present in the spectrum of α²CVn. Of 23 lines chosen for intensity measurement, 14 were found to belong to Group A, 2 to Group B, 7 to be constant and 1 doubtful. One of the B lines, 4076, is a blend; the other, 4131, is mainly due to *Si*II. 4 of the A lines are unblended; so are 3 of the constant lines. It will take too much space to list all the numerous strong laboratory lines of *Ce*II, *Sa*II, and other ionized rare-earths. Instead, we list in Table IX all the Group A lines except those which are mainly due to *Eu*II, *Dy*II, or *Gd*II; all the Group B lines are given in Table X. In these two tables the I.P. and the E.P. of the main contributor are also given. Two *Ce*II lines are plotted in fig. 3.

*Sa*II. Only about 40 per cent. of the stronger laboratory lines are present, and none of the multiplets is complete. The presence of *Sa*II in the star must be regarded as rather doubtful. A few lines cannot, however, be accounted for by anything else. Of the 18 lines chosen for study, 9 are found to belong to Group A (4 of which are unblended), 3 to Group B, and 6 to be constant. One of the B lines, 4262, is mainly due to *Cr*II; and another, 4076, is blended with *Cr*II and *Si*II. The unblended *Sa*II line 4434 is plotted in fig. 1.

*Ti*II. Of the 23 *Ti*II lines chosen for study, 12 are found to belong to Group A, 3 to Group B, and 8 to be constant. Two B lines, 4174 and 4549, are mainly due to *Fe*II. 6 of the A lines are unblended. The intensity curves for four *Ti*II lines are given in fig. 3. It is safe to say that *Ti*II lines tend to vary in the same way as most of the rare-earth lines.

TABLE IX

Group A *Lines*

(Excluding *Eu*II, *Dy*II, *Gd*II)

Wave-length	Elements	Intensity	I.P.*	E.P. Low	E.P. High	Temp. Class
4361·81	*Sa*II	3–1	11·4 *v*	0·54	3·31	III
4424·42	*Sa*II	2–1	...	0·48	3·27	III
4434·04	*Sa*II	4–2	...	0·43	3·21	III
4144·72	*Tb*II	2–1				IV
4213·71	*Tb*II, *Ce*II	3–1				IV
3908·36	*Ce*II	4–3		0·46	3·62	IV
3942·40	*Ce*II	4–2		0·00	3·13	IV, V
4270·59	*Ce*II	4–2		0·56	3·45	V
4363·68	*Ce*II?	3–2		0·49	3·32	IV
4484·87	*Gd*II, *Ce*II	3–1	Blend			IV
4290·13	*Ti*II, *Ce*II (*Cr*I)	5–3	*Ti*II 13·6	1·16	4·04	V
4054·28	*Ti*II	4–2	...	1·89	4·93	V
4300·25	*Ti*II	3–2	...	1·17	4·04	V
4301·79	*Ti*II	3–1	...	1·16	4·02	V
4367·87	*Ti*II, *Sa*II, *O*I?	3–2	...	2·58	5·40	V
4386·79	*Ti*II	3–2	...	2·59	5·40	
4563·81	*Ti*II	4–2	...	1·22	3·92	V
? 4399·72	*Ti*II	3–2?	...	1·23	4·04	V
? 4534·00	*Ti* (*Fe*II)	6–5?	...	1·23	3·95	V
4584·24	*Fe*II (*Sa*II)	7–5	*Fe*II 16·5	2·79	5·49	
? 4087·58	*Fe*II (*Cr*II)	2–1?	...	2·57	5·59	
3933·63	*Ca*II	7–5	11·82	0·00	3·14	II
4077·78	*Sr*II, *Dy*II, *Gd*II?	5–3	*Sr*II 10·98	0·00	3·03	II
4215·47	*Sr*II, *Gd*II	4–3	...	0·00	2·93	II
4422·47	*Y*II (*Ti*II)	3–1	12·3	0·10	2·89	III
4292·98	*Zr*II	2–1	13·97	1·74	4·61	
3957·73	*Gd*II, *Tb*II, *Zr*II (*Dy*II, *Cr*II)	4–1	Blend			
4045·92	*Fe*I, *Zr*II, *Ho*II?	4–2	Blend			
4401·58	(*Fe*I)	2–1	*Fe*I 7·83	3·59	6·39	
4447·79	(*Fe*I, *Al*II)	6–3				
? 4267·09	*C*II?	2–1?	*C*II 24·27	18·0	20·9	
? 4217·94	*La*II? *Gd*II?	3–1?				
4061·83	?	4–2				
4207·84	(*Cr*II?)	4–2				
4621·81	?	7–4?				
? 4241·22	?	2–1?				
? 4471·28	*Ce*II, *Gd*II, *He*I?	4–2?	Blend			

* All the I.P. given in this column are second ionization potentials except that for *Fe*I 4401.

*Fe*II. Of the 23 *Fe*II lines chosen for study, 4 are found to belong to Group A, 9 to Group B, 8 to be constant and 2 doubtful. Among the four A lines, 4296 is blended with *Gd*II and *Ce*II, and 4584 with *Sa*II. The rare-earth contributors are probably responsible for the A characteristic. Another A line, 4534, is mainly due to *Ti*II. Another blend with *Ti*II,

TABLE X

Group B *Lines*

Wave-length	Elements	Intensity	I.P.*	E.P.	
				Low	High
4340·47	*Hγ*	220–250	13·54 *v*	10·16	13·00
4101·74	*Hδ*	220–230	...	10·16	13·16
3970·07	*Hε*	190–220	...	10·16	13·26
4128·09	*Si*II	8–11	16·27	9·79	12·78
4131·04	*Si*II (*Ce*II, *Gd*II)	8–10	...	9·80	12·78
4481·32	*Mg*II (*Gd*II)	8–10	14·97	8·82	11·58
4233·23	*Fe*II (*Cr*II)	4–7	16·5	2·57	5·49
4258·23	*Fe*II	2–4	...	2·69	5·59
4303·29	*Fe*II	3–5	...	2·69	5·56
4385·54	*Fe*II	2–4	...	2·77	5·58
4520·34	*Fe*II	3–5	...	2·79	5·52
4549·62	*Fe*II, *Ti*II	7–9	...	2·82	5·53
? 4173·72	*Fe*II (*Ti*II)	3–4	...	2·57	5·53
4179·24	*Fe*II (*Cr*II, *Zr*II)	3–5	...	2·57	5·52
3905·61	*Cr*II, *Si*I?	4–6	16·6	Unclassified	
4242·53	*Cr*II (*Mn*II)	2–4	...	3·85	6·76
? 4269·33	*Cr*II, *Gd*II	2–3?	...	3·84	6·73
4558·74	*Cr*II (*Gd*II)	4–6	...	4·06	6·76
4588·34	*Cr*II (*Al*II)	3–5	...	4·05	6·74
4002·53	*Tb*II, *V*II	3–5			
? 4024·09	*Tb*II, *Zr*II, *V*II	3–5?			
4032·56	*Tb*II (*Dy*II)	2–4			
4200·82	*Tb*II, *Fe*I, *Mn*II?	2–5			
4325·75	*Fe*I, *Tb*II, *Gd*II	3–4	Blend		
? 4512·01	*Sa*II	1–3?	11·4	0·18	2·92
4075·80	*Ce*II, *Sa*II, *Si*II	3–4	Blend		
3918·64	*Ce*II	2–4			
? 4262·13	*Gd*II, *Sa*II, *Cr*II (*Fe*I)	3–4?	Blend		
? 4312·89	*Ti*II	3–4?	13·6	1·17	4·04
? 4246·49	*Sc*II	2–3	12·80	0·31	3·22

* Except for the *H* lines, the I.P. given are the second ionization potentials.

4549, is found to be a Group B line. In this case the *Ti*II partner probably plays a minor rôle in determining the policy of the line. In general, we may say that *Fe*II lines tend to vary in the opposite manner to the rare-earth and *Ti*II lines. Three *Fe*II lines are plotted in fig. 4, while 4584 is plotted in fig. 3.

*Cr*II. Of the 10 *Cr*II lines chosen for study, 2 are found to be Group A lines, 6 to be Group B lines and 2 to be constant. One of the two A lines, 4088, is mainly due to *Fe*II ; and the other, 4207, is probably not entirely due to *Cr*II, as *Cr*II 4207·34 is a very faint laboratory line. *Cr*II, in general, has a strong tendency to go with *Fe*II. 2 important *Cr*II lines are plotted in fig. 2. It is interesting to mention here an article by Morgan * in which he described the spectrum of the star B.D. – 18° 3789. In the spectrum of this star *Eu*II and *Cr*II lines vary in intensity in opposite phase. The period is 3·18 days. This star must be similar in some respect to

* *Ap. J.*, 74, 24, 1931.

α^2CVn. One difference is that the *Fe*II lines in B.D. – 18° 3789 are constant except the line 4296·61 which goes with *Eu*II. From the foregoing discussion we see that this line must be mainly due to *Gd*II and *Ce*II.

H, *Si*II, *Mg*II. These lines are plotted in fig. 2. There is one thing to be said about these strong lines in the spectrum, namely, the points on the graph scatter more widely from the mean curves than in the case of the weaker lines. This is especially true for *H*δ, *Si*II 4131 and *Mg*II 4481. In the case of *H*δ, the difference of density for different plates is probably one of the factors that lead to the discrepancy ; and for a few plates *H*δ is quite near one end of the region of good focus. For *Si*II 4131, the blend with *Ce*II and *Gd*II is probably the vital factor. *Si*II aligns itself with other B lines, but the rare-earth partners change in the opposite direction all through the cycle, rendering the line more or less constant. If we plot the ratio 4131/4128 against phase, we get a curve similar to the intensity curve of *Eu*II 4205. The data used in plotting the two *Si*II curves in fig. 2 are from 4-prism plates only. The 2-prism data give two very similar curves. In the case of *Mg*II 4481, *Gd*II 4481·06 probably causes the same trouble. The data for the hydrogen lines are from the 2-prism plates.

*Ca*II. K line is plotted in fig. 1. The data for it are rather scanty, but are perhaps enough to show that it is a Group A line. The spectroscopic parallax of the star is 0″·034, and the trigonometrical parallax is 0″·044,* therefore no prominent interstellar calcium lines are to be expected. The interstellar component, if present, will hardly be separable from the stellar K line, since the star as a whole probably has a constant velocity pretty near to zero.

λ 4447·8. This is definitely a Group A line. *Fe*I 7·73 is not enough to account for its intensity and behaviour, because most other *Fe*I lines are weak and constant. Furthermore, several other lines in the same *Fe*I multiplet are missing, namely, 4408, 4442, 4494·6 and 4528·6. Another possible contributor to this line is *Al*II 4447·8 ; but, similar to *Fe*I, other *Al*II lines in the spectrum are weak and do not behave in the same manner. We need something else to account for this line. As in the case of λ 4201, 4448 is one of the strongest unidentified lines in early-type spectra.

λ 4076·9. This is the line which was claimed to have a double maximum in the intensity curve.† We plot the data obtained for this line in fig. 4, crosses for 4-prism data, and dots for 2-prism data. The material is not quite enough to bring out anything definite. But within the limit of observational error, it is safer to regard the line as probably constant. The identification is also quite uncertain. Both *Si*II 6·78 and *Cr*II 6·88 are very weak laboratory lines.

Looking at Tables IV, VI, IX and X, we see that the Group A lines have in general lower E.P. than the Group B lines. The variation of line intensity as a whole may be just an effect of excitation. We shall come to this point again later on.

The present results with regard to line behaviour agree in general with

* Adams and Joy, *Ap. J.*, **56**, 256, 1922.

† See Markov's paper, *Ap. J.*, **72**, 301, 1930.

work by earlier observers. The exceptions are given below. Markov's paper is taken as a summary of the work done on this star up to that time (1932). Letters at the head of each paragraph denote groups assigned to the lines in that paper by Markov. Letters in parentheses are what we have now determined :

A : 4181 (C), 4262 (B?), 4269 (B?), 4523 (C).
A? : 3925·30 (C?).
B : 3942·40 (A), 4055·30 (A), 4123 (C), 4303 (C), 4622 (A?).
C : 4000·24 (A), 4024·09 (B?), 4061·83 (A), 4063·59 (A), 4078 (A), 4125 (A), 4520 (B), 4400 (A), 4534 (A?), 4584 (A).
C? : 4368 (A), 4174 (B?).
D : 4077 (C).
E : 4087·58 (A?).

C means constant ; D means double maximum ; and E means varying irregularly. Besides the above disagreement, 35 lines which are now found to be variable (A or B) were not given in Markov's list.

The Light Curve

After the determination of the light curve of α^2CVn by Guthnick and Prager in 1914, no other recent determination has been known. The variation is too small to detect visually. With the kind permission of Sir A. S. Eddington, the star was put on the observation programme of Cambridge University Observatory. Mr. H. E. Green, who is in charge of the photometric work, observed α^2CVn on 17 fine nights. The time ranged from March to May 1938, corresponding closely to that during which the 1938 series of spectrograms were taken. The photoelectric photometer was attached to the Sheepshanks 12-inch refractor, and δ UMa was selected to be the comparison star. The data are properly weighted and combined, and are summarized in Table XI. The apparent magnitude of δ UMa is taken as 3·44. Phase is also calculated from Farnsworth's formula.

TABLE XI

Light Variation of α^2CVn

Phase	*m*
d	m
0·67	2·810
0·81	2·823
1·51	2·797
1·67	2·808
1·92	2·800
2·68	2·844
2·74	2·828
2·89	2·837
3·30	2·830
4·34	2·830
4·42	2·837
5·01	2·822

These values are plotted in fig. 7 in order to compare them with the variations in colour temperature and line intensities. The curve shows that

the apparent magnitude of α^2CVn varies between $2^m.802$ and $2^m.836$, and that light maximum occurs at the phase $1^d.5$ approximately. The range of variation, $0^m.034$, is somewhat smaller than that given by Guthnick and Prager, $0^m.051$.

The Colour Temperature

In the Greenwich publication of colour temperature measurements,* α^2CVn was listed among the standard stars, and its gradient was given as −0·06. Owing to the slight change in apparent magnitude and the behaviour of the spectral lines, it was thought worth while to examine the colour temperature, and see whether it shows a periodic variation also.

Mr. D. L. Edwards of Norman Lockyer Observatory kindly consented to include α^2CVn in his colour temperature programme. He and Mr. D. R. Barber obtained about twenty plates in the spring of 1938, at the same time

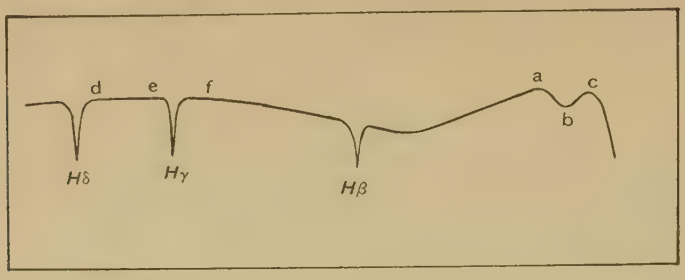

Fig. 5.—*Microphotometric Tracing of a Colour Temperature Plate.*

as that in which the 1938 series of spectrograms and the photometric data for light curve were taken. Fourteen plates were brought to Cambridge by the writer and measured there. The other six plates are of comparatively inferior quality. The plates were taken with the McClean 12-inch prismatic camera, the 20° objective prism being covered with a 4-inch diaphragm. The dispersion is 32·7 A. per mm. at $H\gamma$. Ilford Hypersensitive Panchromatic plate was used. On each plate are three spectra, one of α^2CVn and two of the comparison stars, and twelve calibration marks. The calibration marks were taken with a tube sensitometer, 6 with blue light and 6 with red light. Two Wratten filters (Nos. 47A and 71A) were used one after the other to secure the red and blue light. The intensities of the light from the six tubes are in the ratio 1 : 2 : 4 : 8 : 16 : 32, so that the "log I" form a linear sequence.†

From each plate, four tracings were obtained with the Cambridge microphotometer, three for the three stellar spectra and one for the calibration marks. A typical tracing of the spectrum is shown in fig. 5. The two maxima and one minimum in the red region are present on every tracing, and are therefore due to characteristics of the plate, or of the optical train, or of both. Because of that, three points are chosen at *a*, *b* and *c*, corresponding quite closely to the two maxima and the minimum, as the change

* *Observations of Colour Temperature of Stars*, 1932.

† *Bulletin of Norman Lockyer Obs.*, No. 1, p. 14, 1938.

of photographic density of the continuous background with respect to wavelength is smallest at these places. Three other points are chosen in the blue region to make a total of six for the measurement of gradients. They are as follows :—

Red	Blue
λ 6082 – *a*	λ 4155 – *d*
λ 6273 – *b*	λ 4266 – *e*
λ 6427 – *c*	λ 4429 – *f*

The Balmer absorption lines are used as references in locating these points. The formula employed for the calculation of gradients is that given on p. 19 of the Greenwich publication. The result is given in Table XII.

TABLE XII

The Colour Temperature of α^2*CVn*

Plate No.	Date	Stand. Stars	ΔG	Atmos. Red.	G_s	G	G_{av}	Phase
	1938							d
5432	Mar. 4·0	β UMa	−·03	−·02	−·02	−·07	−·12	2·65
		δ Leo	−·51	+·05	+·29	−·17		
5468	May 19·93	η UMa	—	—	−·23	—	−·35	3·01
		δ Leo	−·88	+·24	+·29	−·35		
5469	21·89	η UMa	+·21	−·02	−·23	−·07	−·22	4·97
		δ Leo	−·80	+·13	+·29	−·38		
5472	22·89	η UMa	+·37	−·02	−·23	+·12	+·02	0·50
		δ Leo	−·52	+·16	+·29	−·07		
5474	25·94	η UMa	+·11	−·05	−·23	−·17	−·14	3·55
		δ Leo	−·70	+·31	+·29	−·10		
5475	28·91	η UMa	+·14	−·04	−·23	−·13	−·07	1·05
		α CBor	−·02	−·01	+·01	−·02		
5476	June 2·91	η UMa	+·30	−·05	−·23	+·02	−·02	0·58
		α CBor	−·06	−·02	+·01	−·07		
5478	9·91	η UMa	+·11	−·05	−·23	−·17	−·14	2·11
		α CBor	−·08	−·03	+·01	−·10		
5481	10·91	η UMa	+·36	−·05	−·23	+·08	+·07	3·11
		α CBor	+·09	−·04	+·01	+·06		
5482	16·90	η UMa	+·10	−·05	−·23	−·18	−·18	3·64
		α CBor	−·23	+·05	+·01	−·17		
5484	20·90	η UMa	+·20	−·07	−·23	−·10	−·12	2·17
		α CBor	−·08	−·07	+·01	−·14		
5489	July 2·95	η UMa	+·19	−·20	−·23	−·24	−·24	3·28
		α CBor	—	—	+·01	—		
5490	12·89	η UMa	+·19	−·13	−·23	−·17	−·21	2·28
		α CBor	−·13	−·14	+·01	−·26		
5493	26·89	η UMa	+·34	−·14	−·23	−·03	−·11	5·34
		α CBor	−·10	−·11	+·01	−·20		

Notes.—Stand. Stars = Standard stars in the Greenwich publication.
ΔG = observed difference of gradients.
Atmos. Red. = Correction for atmospheric reddening.
$= A(\sec z_2 - \sec z_1)$, $A = 0{\cdot}5$.
G_s = Gradient of the comparison star.
G_{av} = Average gradient for each plate.
Phase—calculated from Farnsworth's formula.

In fig. 6 (*a*) we plot the average value of G for each plate against phase. Except for two near the phase $3^d{\cdot}0$, all the points lie pretty close to the mean curve. In the 1932 Greenwich publication, the value of A, the coefficient of atmospheric reddening, adopted is 0·5, and the value of ϕ_0 was determined to be 1·16, corresponding to a temperature T_0 equal to 14,300° K. In a later publication, ϕ_0 was redetermined, giving $\phi_0 = 1{\cdot}0$, $T_0 = 18{,}000°$; and the value of A adopted is 0·31, which is a more universally accepted value. In fig. 6 (*b*) we plot the points obtained by changing the value of A from 0·5 to 0·31; the scattering from the mean curve is somewhat smaller than before, but we must bear in mind that the gradients of the standard stars used in the calculation were determined under the assumption $A = 0{\cdot}5$. In fig. 6 (*c*) we plot only those values of G which are compared with η UMa. The scattering from mean curve is even smaller in this case. And in fig. 6 (*d*) the intensity curve of the spectral line λ 4201 is reproduced for comparison.

Recently Hunter* rediscussed the Greenwich data for α^2CVn given in the 1932 publication, and concluded that any possible variation of gradient in α^2CVn were smaller than could be detected on Greenwich plates. He plotted the observed gradient against phase calculated from formulæ given by Belopolsky and Markov, and obtained a scatter diagram showing no trace of regular variation. The writer had done the same thing in the course of this work, but instead of Belopolsky and Markov's formulæ, the writer employed Farnsworth's formula for the calculation of phase. He, too, found no evidence of regular variation on the diagram obtained.

The Sidmouth plates give a mean gradient of $-0{\cdot}12$, which is smaller than the Greenwich value $-0{\cdot}06$, indicating higher temperature. The Greenwich result is based on 29 comparisons with 7 standard stars on 18 nights between 1928 May 8 and 1929 May 3. The present result is based on 26 comparisons with 4 of the above 7 standard stars on 14 nights between 1938 March 3 and 1938 July 26. The method of calibration is different in the two cases. The present results indicate a regular variation of colour temperature, G varying between 0·0 and $-0{\cdot}20$, or between $+0{\cdot}05$ and $-0{\cdot}20$ if we take only comparisons with the standard star η UMa. The data are not sufficient to justify regarding the evidence as conclusive. Nevertheless, they are given here for the reference of future observers.

Discussion

In fig. 7 we put together for comparison the light curve, the colour temperature curve, and the intensity curve of two representatives from the two groups of spectral lines. The colour temperature curve is the same as that in fig. 6 (*c*) (*cf.* η UMa only), except that the unit of the vertical scale is shifted from gradient to absolute temperature, adopting the revised Greenwich zero point $\phi_0 = 1{\cdot}0$, $T_0 = 18{,}000°$ K, which is probably too high.† Since we are only interested in the variation of temperature during each

* *Observatory*, **62**, 219, 1939.

† Hunter stated in the above-mentioned reference that 1·07 is considered to be the most probable zero point.

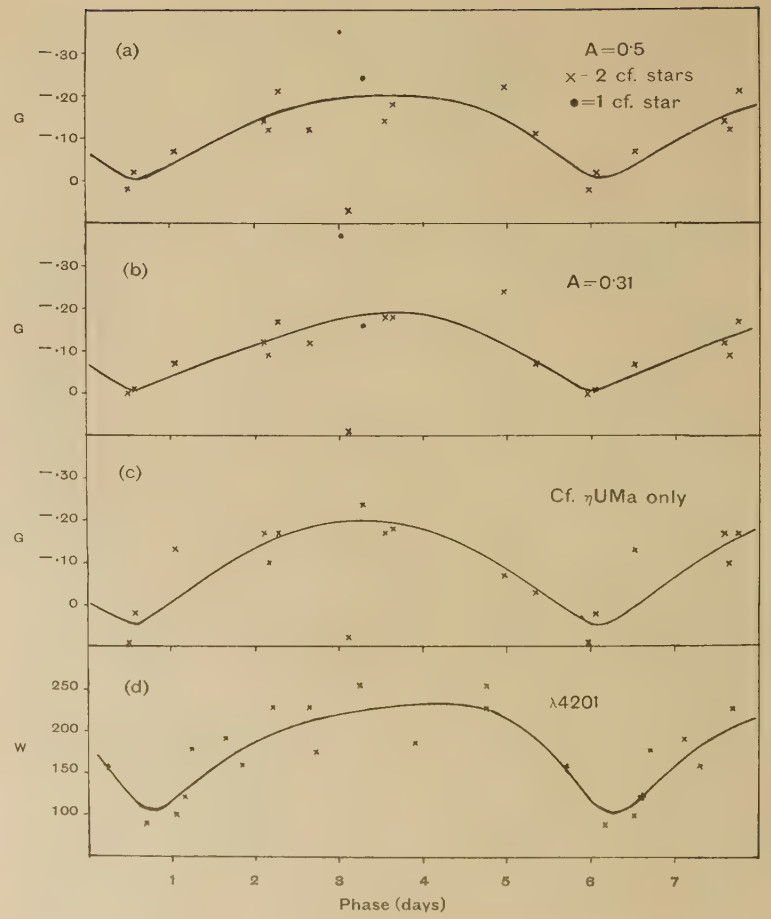

FIG. 6.—*Variation of Colour Temperature.*

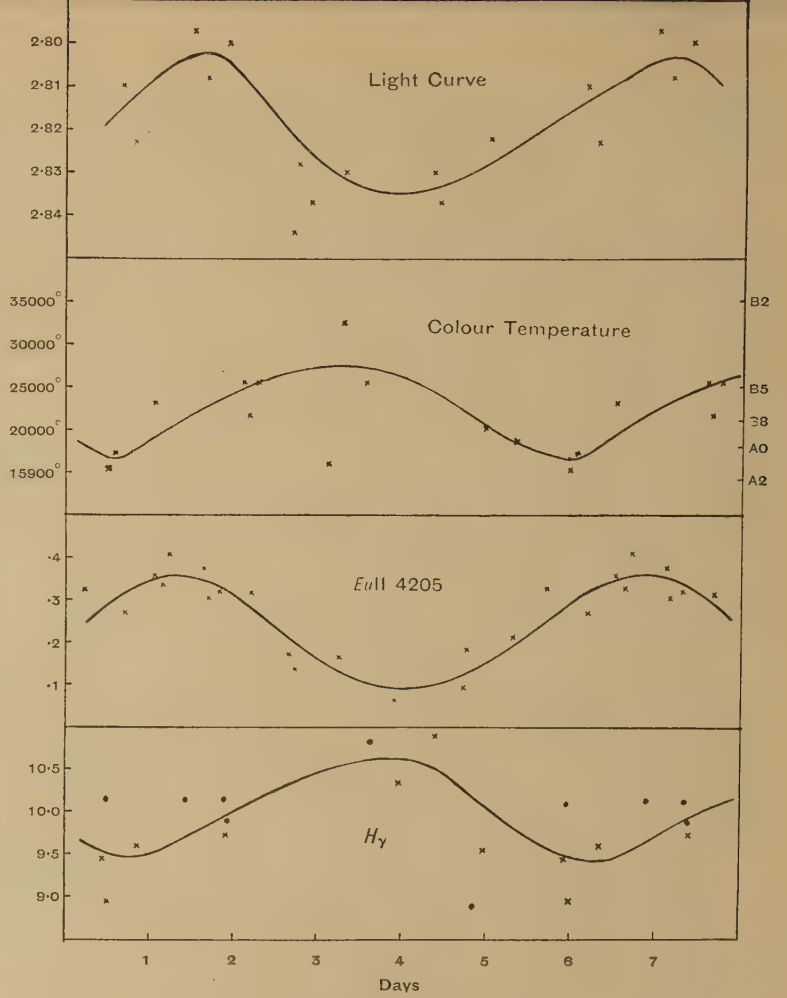

FIG. 7.—*Comparison of Apparent Magnitude, Colour Temperature and Equivalent Widths of Lines.*

light cycle, any error in the zero point does not matter very much, nor does any error in the coefficient of atmospheric reddening. On the right-hand side of fig. 7 (*b*) the spectral type is put down for reference ; it is also deduced from the data given in the Greenwich publication.

From fig. 7 we see that colour temperature is minimum near light maximum and is maximum near light minimum. Our data for the light curve are not quite sufficient for locating the point at which the light maximum actually occurs, or for deciding whether the light curve is asymmetrical in shape. We shall only say that colour temperature minimum occurs near light maximum and *vice versa*, if our determinations of both are correct. Also, Group A line maximum occurs near light maximum and temperature minimum ; while Group B line maximum occurs near light minimum and temperature maximum. On the graph it appears as if colour temperature and Group B line minimum occurs about 0·8 day before light and Group A line maximum.

The range of colour temperature corresponds roughly to a change of spectral type from A0 to B5 ; but throughout the cycle there is no trace of *He*I 4026. Though 4471 is present, it is quite probably due to *Ce*II and *Gd*II, and is either a Group A line or a constant line. Besides, there is also little evidence for the presence of other high-excitation lines, such as *S*II, *O*II and *N*II. It does not seem likely that all these absences are to be attributed to low abundance.

The Balmer lines of hydrogen are usually observed to have maximum intensity at spectral type A0 or later. As the temperature increases, we expect them to decrease in strength, but they increase in our case. Likewise, *Si*II, *Mg*II, *Fe*II and *Cr*II should all decrease in strength as the temperature goes higher than that at A0. This, too, is not found to be the case. The faintness of the K line is the only indication that the spectral type of the star may be earlier than A0, unless we attribute the faintness to low abundance.

In a previous note on this star,* the writer mentioned that perhaps at the phase when the Balmer absorption lines increase in strength, the simultaneous increase of Paschen continuous absorption diminishes relatively the intensity of the continuous spectrum in the red, and hence increases the colour temperature at light minimum. The head of the Paschen series is at λ 8200 approximately. It is difficult to see whether the Paschen continuous absorption extends as far to the shorter wave-length as λ 6400 (the place where points were chosen for the measurement of gradient) and diminishes the intensity of the continuous spectrum there to such an extent as to produce an appreciable effect on the measured value of the gradient. An experimental test of this point is made difficult by the presence of several strong atmospheric absorption bands in that region.

As mentioned above, the evidence for a regular periodic variation of colour temperature is not very conclusive. The only alternative to the observed manner of variation would be a constant temperature, for obviously the temperature cannot vary the other way. A fall of temperature from

* *Observatory*, **62**, 81, 1939.

light maximum to light minimum can hardly be reconciled with the weakening of the low excitation Group A lines. If the temperature is constant, some other cause must be sought to explain the behaviour of the two groups of lines.

The work of Barbier, Chalonge and their colleagues at Jungfraujoch on the continuous spectra of stars in the ultra-violet region * reveals that the continuous absorption beyond the head of the Balmer series in α^2CVn is smaller than in ordinary Ao stars. The mean value of Balmer jump (D) for 15 Ao stars is 0·47 ($\log_{10} I$ unit), whereas for α^2CVn, D is 0·29. For 3 Ao stars, the mean value of D is 0·30, and for α And, another peculiar star, $D = 0{\cdot}27$. The Balmer Jump is a better indication of the hydrogen content than the intensity of the Balmer lines in the photographic region, because the latter is increased by the Stark effect. This means that the hydrogen content in α^2CVn and α And is smaller than in ordinary main-sequence Ao stars.

According to Russell †, *Fe*II with an I.P. of 16·5 volts should have its maximum at a temperature higher than that at which *H* reaches maximum, whereas the observed *Fe*II maximum is at F5. This discrepancy he explains as being due to the great excess of *H* in the stellar atmosphere. The number of hydrogen ions increases as temperature rises; these ions increase the general opacity, "raise the photosphere", reduce the effective number of *Fe* ions, and consequently weaken the *Fe*II lines. The same explanation applies to other ionized metals. The fact that *Fe*II and *Cr*II lines in α^2CVn are strengthened at temperature maximum can therefore be qualitatively explained by the comparative deficiency of *H* in the star. The temperature range in α^2CVn is possibly such that *Ti*II is of maximum strength at temperature minimum (observed *Ti*II maximum is at F8 for ordinary stars), and *Fe*II is of maximum strength at temperature maximum. A reasonable estimate would be that corresponding to the spectral range A3 to Ao. We shall come back to this point later on.

The unusual strength of the rare-earth lines in α^2CVn can only be attributed to abundance. Since *Eu*II and *Sa*II are the only two singly-ionized rare-earth elements whose spectra have been completely analyzed, and *Sa*II is only doubtfully present in α^2CVn, we shall now discuss *Eu*II in greater detail.

The first ionization potential of europium is 5·64 volts.‡ At the temperature corresponding to type Ao, practically all the europium atoms are ionized. This agrees with the absence or extreme faintness of *Eu*I lines in α^2CVn. The second ionization potential of europium is 11·4*v*. § Therefore at 10,000° most europium atoms are doubly ionized. We have no knowledge of the *Eu*III spectrum, but it is not impossible that some of the unidentified Group B lines may be due to *Eu*III or other doubly-ionized metals.

As pointed out above, the large intensity variation of the two ground

* *Annals d'Astrophysique*, **2** and **4**, 1938.
† *Ap. J.*, **78**, 239, 1933.
‡ Russell and King, *Phys. Rev.*, **46**, 1023, 1934.
§ Albertson, *Phys. Rev.*, **45**, 499, 1934.

state lines of *Eu*II, 4130 and 4205, might be partly due to blending. The ratio of the mean equivalent widths of these two lines at maximum and at minimum is 4·2. The other member of the same multiplet, λ 3819·65 ($a^9S_4^0 - z^7P_2$), is beyond the range of our spectrum. Earlier observers have reported it as varying in the same manner as 4205. The three *Eu*II lines in the spectrum which are not seriously blended and whose low level is $a^7S_4^0$ (0·21*v*) are 3907, 3930 and 4435. The ratio of mean equivalent widths of these lines at maximum and at minimum is about 2·2. At minimum, the two lines from the ground state are only slightly fainter than the three lines from $a^7S_4^0$ level; while at maximum, the former are very much stronger than the latter.

The great strengthening of 4205 and 4130 in the solar chromosphere with respect to the reversing layer is usually regarded as being due to the increase of ionized atoms as a result of smaller pressure. The difficulty in this particular case is that *Eu*I lines are not strengthened in the reversing layer. In fact, *Eu*I is regarded as absent in both the chromosphere and the reversing layer. Nevertheless, pressure change might be one of the factors which cause the spectral lines to behave as observed in α^2CVn, and a rough calculation shows that it is not impossible.

Take Saha's ionization equation; neglect the term involving the partition function, and disregard the effect due to the mixture of several elements with different ionization potentials. Instead of colour temperature, we adopt the ionization temperature scale for stars, namely, 9,000° for A3, 10,000 for A0 and 15,000 for B5. In the following equations x is the fraction of europium atoms which are doubly ionized, $(1-x)$ is the fraction singly ionized (it is assumed that no neutral europium atoms are present). Subscript 1 refers to *Eu*II maximum and 2 to *Eu*II minimum. I = ionization potential of *Eu*II = 11·4 volts.

$$\log \frac{x_1}{1-x_1} = -\frac{5040\,I}{T_1} + \frac{5}{2}\log T_1 - 6{\cdot}5 - \log P_1,$$

$$\log \frac{x_2}{1-x_2} = -\frac{5040\,I}{T_2} + \frac{5}{2}\log T_2 - 6{\cdot}5 - \log P_2.$$

Assume $P_1 = 10^{-4}$ atm. Then $x_1 = 0{\cdot}982$ for $T_1 = 10{,}000°$, and $x_1 = 0{\cdot}915$ for $T_1 = 9{,}000°$.

Let $S = \dfrac{1-x_1}{1-x_2}$ = ratio of *Eu*II atoms at maximum to that at minimum. For 4205 and 4130, S is about 4. For the other three *Eu*II lines whose lower energy level is $a^7S_4^0$, S is about 2. The mean value of S for all the five *Eu*II lines is about 3.

Case 1. Assume a constant pressure of 10^{-4} atm. and a varying temperature. Take $T_1 = 10{,}000°$ and $T_2 = 15{,}000°$.

Then we get $S = 220$.

Case 2. Assume the same constant pressure and a temperature varying in a smaller range. Take $T_1 = 9{,}000°$ and $T_2 = 10{,}000°$.

Then we get $S = 4{\cdot}7$.

Case 3. Assume a varying pressure and a constant temperature of 10,000°.

If we take $S=4$, then we get $P_1=4P_2$;
$S=3$, $P_1=3P_2$;
$S=2$, $P_1=2P_2$.

Case 4. Again assume a varying pressure, but take a constant temperature of 9,000°.

If we take $S=4$, then we get $P_1=4{\cdot}3P_2$;
$S=3$, $P_1=3{\cdot}2P_2$;
$S=2$, $P_1=2{\cdot}1P_2$.

Case 5. Assume that both pressure and temperature vary. Take $T_1=10{,}000$, and $T_2=15{,}000$.

If we use $S=4$, we get $P_1=\frac{1}{114}P_2$;
$S=3$, $P_1=\frac{1}{76}P_2$;
$S=2$, $P_1=\frac{1}{57}P_2$.

Case 6. Again assume that both pressure and temperature vary. This time take $T_1=9{,}000°$ and $T_2=10{,}000°$.

If we use $S=4$, we get $P_1=0{\cdot}76P_2$;
$S=3$, $P_1=0{\cdot}56P_2$;
$S=2$, $P_1=0{\cdot}37P_2$.

Case 1 differs so much from observed results that it requires no further consideration. Case 2 gives a value of S which is a little bigger than the observed value. Cases 3 and 4 postulate a constant temperature, and we get a moderate decrease of pressure as *Eu*II goes from maximum to minimum. Case 5 yields a big change of pressure the other way: minimum pressure at minimum temperature. Case 6 gives a much smaller change of pressure in the same way as Case 5.

In order to decide which case fits the behaviour of the other spectral lines best, let us take *Ti*II and *Fe*II for a test. Let S_0 be the ratio of the mean equivalent width of the variable lines at light maximum to that at light minimum, and define the theoretical value of S, S_c, as follows:—

$$S_c=\frac{1-x_1}{1-x_2}\exp\left[-11{,}600\,E\left(\frac{1}{T_1}-\frac{1}{T_2}\right)\right],$$

where E is the mean excitation potential in volts of the lower levels of the variable lines. For *Eu*II, the exponential factor is practically unity, and was therefore neglected in previous calculations.

For the 8 variable *Ti*II lines, 4054, 4290, 4300, 4302, 4368, 4387, 4400 and 4564, mean E.P. = 1·64 v., I.P. = 13·6 v. and $S_0=1{\cdot}83$. For the 6 variable *Fe*II lines, 4179, 4233, 4258, 4303, 4385 and 4520, mean E.P. = 2·68 v., I.P. = 16·5 v. and $S_0=0{\cdot}65$. P_1 is assumed to be 10^{-4} atm. in all cases. The results are given in Table XIII. In the table, the denominator and the numerator of the ratio $\frac{1-x_1}{1-x_2}$ are expressed in percentage of atoms which are singly ionized.

TABLE XIII

Case	Pressure	Temperature	*Ti*II			*Fe*II		
			$\frac{1-x_1}{1-x_2}$	S_e	S_0	$\frac{1-x_1}{1-x_2}$	S_e	S_0
1	$P_1=P_2$	$T_1=10{,}000°$ $T_2=15{,}000°$	$\frac{18\cdot3}{0\cdot04}$	230	1·83	$\frac{86\cdot6}{0\cdot5}$	61·4	0·65
2	$P_1=P_2$	$T_1=9{,}000°$ $T_2=10{,}000°$	$\frac{62\cdot3}{18\cdot3}$	2·76	...	$\frac{98\cdot6}{86\cdot6}$	0·81	...
3	$P_1=3P_2$	$T_1=T_2$ $=10{,}000°$	$\frac{18\cdot3}{7}$	2·6	...	$\frac{86\cdot6}{68\cdot3}$	1·27	...
4	$P_1=3\cdot2P_2$	$T_1=T_2$ $=9{,}000°$	$\frac{62\cdot3}{34}$	1·83	...	$\frac{98\cdot6}{95\cdot7}$	1·03	...
5	$P_1=\frac{1}{10}P_2$	$T_1=10{,}000°$ $T_2=15{,}000°$	$\frac{18\cdot3}{3\cdot2}$	3·03	...	$\frac{86\cdot6}{23\cdot2}$	1·33	...
6	$P_1=0\cdot56P_2$	$T_1=9{,}000°$ $T_2=10{,}000°$	$\frac{62\cdot3}{28\cdot6}$	1·77	...	$\frac{98\cdot6}{92}$	0·76	...

From Table XIII we see that Case 6 fits *Ti*II and *Fe*II better than the other cases. For *Ti*II, excitation does not play an important part. It is the ratio of doubly-ionized to singly-ionized atoms that decides the strength of the lines. The great increase of doubly-ionized atoms causes the lines to weaken at temperature maximum. For *Fe*II, on the other hand, ionization is not an important factor. The great majority of the atoms are singly ionized within the assumed range of temperature and pressure; the number of neutral atoms is negligible and that of the doubly-ionized atoms is also quite small compared with that of the singly-ionized atoms. It is excitation that causes these subordinate lines to strengthen at temperature maximum. Case 6 also fits *Cr*II excellently. For *H*, *Si*II, *Mg*II, *Ca*II, *Sr*II, *Zr*II and *Y*II, Case 6 also assigns them into the right group, but predicts a bigger change of intensity than that observed. In a few cases, this discrepancy can be attributed to blending.

Summary

Along with *Eu*II, *Gd*II and *Dy*II are found to be present in the atmosphere of α^2CVn. Lines due to these two elements are found to behave in the same manner as *Eu*II lines. *Ce*II, *Tb*II and *Sa*II are probably present. For the other rare-earth elements, the data available are not sufficient either to establish their presence or to eliminate them from further consideration.

The light curve is determined with a photoelectric photometer. The

apparent magnitude of the star is found to vary in a period of about 5·47 days, the range of variation being only $0^m.035$. This confirms roughly earlier observations by Guthnick and Prager.

The colour temperature is found to vary during each light cycle, minimum occurring near light maximum and *vice versa*. The evidence is, however, not conclusive. The temperature change corresponds to a change of spectral type from A0 to B5, but the spectrum does not reveal such a big change. *He*I is probably absent all through the cycle, so are other high excitation lines, such as *S*II, *O*II and *N*II.

Two groups of variable lines are present in the spectrum. One group (A) strengthens at light maximum and colour temperature minimum, whereas the other group (B) strengthens at light minimum and colour temperature maximum. To Group A belong *Eu*II, *Dy*II, *Gd*II, *Ce*II lines, K line of *Ca*II, the majority of *Ti*II lines, and probably *Sr*II, *Sa*II, *Y*II and *Zr*II. To Group B belong the hydrogen lines, *Si*II 4128 and 4131, *Mg*II 4481, as well as most of the *Fe*II and *Cr*II lines. The Group B lines have in general higher I.P. and higher E.P. than Group A lines. If we adopt the temperature range 9,000° to 10,000° (corresponding to spectral type A3 to A0) and a twofold increase of electron pressure (10^{-4} atm. at 9,000° and $2 \cdot 10^{-4}$ atm. at 10,000°), we can then explain the spectral change in terms of thermal ionization and excitation.

Several Group B lines which were formerly attributed to terbium are now shown to be due to something else. The lack of uniformity in the behaviour of *Tb*II lines throws doubt on its presence. Among the neutral metallic lines, only those strong lines due to *Mg*I, *Fe*I and *Cr*I are definitely present. They are mostly faint and quite constant.

The Balmer jump in α^2CVn was observed by Barbier, Chalonge and their colleagues to be smaller than in other main-sequence A0 stars. This may indicate a smaller hydrogen content in the star, and may have something to do with the unusual abundance of the rare-earth elements and the behaviour of the spectral lines.

Acknowledgment

This problem was suggested by Professor F. J. M. Stratton and the investigation was carried out under his supervision. For his constant help and encouragement, the writer wishes to express his deep gratitude. The writer would also like to express his sincere thanks to Mr. D. L. Edwards and Mr. D. R. Barber of Norman Lockyer Observatory for taking the colour temperature plates; to Mr. H. E. Green of Cambridge University Observatory for taking the photometric data for the light curve; and to Dr. A. D. Thackeray for several useful suggestions and constant help in the spectrophotometric side of the work. Special thanks are due to Dr. W. Albertson for sending unpublished data on *Eu*II and *Gd*II multiplets.

Solar Physics Observatory,
Cambridge:
1939 *November* 16.

STELLAR PARALLAXES DETERMINED PHOTOGRAPHICALLY AT THE ROYAL OBSERVATORY, CAPE OF GOOD HOPE (ELEVENTH LIST)

(Communicated by H.M. Astronomer)

The form of publication is similar to that of previous lists.

Most of the stars were observed on account of their proper motion; an increasing proportion belongs to the Cape Astrographic Zone, $-40°$ to $-52°$. There are a few double stars observed because of their dynamical parallax. No. 956 was observed merely on account of spectral type. Stars not observed on account of large proper motion can generally be identified from the fact that no proper motion is given in the table except that in R.A. derived from the parallax plates.

The following notes on individual stars may be useful :—

No. 224.—This star, observed previously, has been unintentionally re-observed. The result given is for the combined series of observations.

Nos. 767 *and* 770.—Canopus and Sirius. The observations have been continued for eleven epochs. For each star there are two series of observations, those under (1) having shorter exposures with brighter comparison stars than (2). For Canopus a 5-magnitude filter was used in (1), for the other series and for both the series for Sirius a 10-magnitude filter was used. The results for Canopus are very accordant, but for Sirius (1) the first two epochs are very discordant, requiring a considerably larger parallax—the influence of these two epochs is reflected in the larger parallax. The measures for Sirius were corrected for orbital motion by Volet's orbit (*Bull. Astr.*, 7, 30). The difference of proper motion from that derived from meridian observations is large.

No. 959 is C.P.D. $-84°$ 263 and is the star of large proper motion in this region. Ci. 20 gives C.P.D. $-84°$ 264, but there is no star of the proper magnitude in this position. C.P.D. $-84°$ 262 has nearly the declination given for 264, but precedes it by 40^s.

No. 974.—The position given here is the correct one. The star precedes B.D. $-8°$ 4352 by $3^s{\cdot}4$ and not 34^s as given by Wolf and reproduced in several parallax lists. Our number 741 was observed erroneously for Wolf 629.

Nos. 999 *and* 1000.—*Harvard Circular* 310 and Ci. 20, 1463, give the wrong identification of the star with considerable proper motion in this region.

The number of large parallaxes is unexpectedly great.

No.	Name and D.M. No.	Mag. Vis. Ptg.	Spec. Type	R.A. Dec. (1900·0)	Unit 0″·001 Proper Motion R.A.	Proper Motion Dec.	P.E. Unit Weight	Parallax	P.E.
				h m s					
923	ζ Tucanæ	4·34	F8	0 14 52	+1708	+1163	34	+146	± 11
	P.G.C. 55	4·84		−65° 27′·7	+1680				± 12
924	13 Ceti	5·24	Go	0 30 06	+ 410	− 20	23	+ 77	± 9
	P.G.C. 116	5·80		− 4° 8′·6	+ 375				± 7
925	G.C. 807	7·05	Go	0 35 43	+ 9	− 98	21	+ 54	± 7
	−8° 117	7·61		− 7° 46′·7	+ 5				± 5
926	Z.C. 339	7·9	Ko	0 41 01	+ 278	− 66	19	+ 80	± 7
	−42° 249*p*	8·8		−42° 27′·2	+ 254				± 7
	Z.C. 340	...	...	0 41 02	+ 268	− 84	27	+ 74	± 10
	−42° 249*f*	9·5		−42° 27′·2	+ 250				± 10
	Mean				+ 273	− 75	...	+ 78	± 6
					+ 252				± 6
927	G.C. 1023	6·76	Go	0 46 04	+ 247	− 128	26	+ 46	± 9
	−5° 138	7·32		− 5° 34′·8	+ 242				± 9
928	Ci. 18, 125	8·9	...	0 52 16	− 270	− 220	18	+ 66	± 6
	−2° 129	11·0		− 2° 21′·1	− 271				± 6
929	−68° 41	...	...	1 06 43	+ 430	+ 580	22	+109	± 8
		11		−67° 59′·7	+ 320				± 6
930	−16° 214	9·6	Ko	1 12 37	+ 300	− 460	31	+ 58	± 10
	A.G. 324	10·6		−16° 1′·0	+ 272				± 7
931	G.C. 2201	7·06	Go	1 44 03	+ 386	+ 159	27	+ 60	± 8
	−42° 638	7·5		−41° 59′·9	+ 382				± 8
932	Z.C. 961	9·0	Go	1 59 33	+ 369	+ 49	32	+ 16	± 10
	−41° 574	9·5		−40° 57′·0	+ 355				± 10
933	G.C. 2500	7·2	Go	1 59 54	+ 324	+ 47	23	+ 46	± 7
	−46° 604	7·8		−45° 53′·7	+ 316				± 8
224	P.G.C. 532	6·38	Go	2 14 30	− 231	+ 450	24	+ 74	± 5
	−26° 828	7·5		−26° 25′·1	− 247				± 1
934	κ Fornacis	5·37	F5	2 17 58	+ 200	− 57	28	+100	± 8
	P.G.C. 543	6·1		−24° 16′·2	+ 123				± 6
935	F.S. 784	9·3	M	2 52 59	+ 168	+ 232	29	+ 16	± 8
	−50° 869	10·8		−50° 36′·0	+ 128				± 8
936	Co.D. −50° 870	9·0	...	2 53 04	...	...	25	− 11	± 7
	C.P.D. −50° 397	10·9		−50° 36′·7	− 8				± 7

No.	Name and D.M. No.	Mag. Vis. Ptg.	Spec. Type	R.A. Dec. (1900·0)	Unit 0″·001 Proper Motion R.A.	Proper Motion Dec.	P.E. Unit Weight.	Parallax	P.E.
				h m s					
937	G.C. 3961	7·10	Go	3 13 58	+ 252	− 105	34	+ 61	± 11
	−3° 534	7·66		− 3° 12′·3	+ 225				± 7
938	P.G.C. 753	5·83	Fo	3 14 07	+ 136	− 49	28	+ 24	± 8
	−19° 651	6·7		−18° 55′·4	+ 119				± 6
939	53 Eridani	3·98	Ko	4 33 36	− 73	− 158	20	+ 35	± 7
	P.G.C. 1091	4·98		−14° 30′·0	− 100				± 5
940	P.G.C. 1098	5·61	G5	4 34 44	+ 123	− 125	28	+ 3	± 10
	−14° 936	6·39		−14° 33′·2	+ 102				± 7
941	α Cæli	4·52	F2	4 37 20	− 148	− 81	33	+ 71	± 10
	P.G.C. 1110	4·86		−42° 03′·3	− 163				± 8
942	G.C. 6757	8·6	Ko	5 23 29	− 320	− 798	32	+ 95	± 11
	−3° 1110	9·6		− 3° 33′·6	− 333				± 8
943	Ross 797	...	...	5 49 24	+ 170	− 500	25	+ 7	± 8
	Ci. 20, 357	11·6		−14° 23′·1	+ 139				± 8
944	P.G.C. 1494	4·68	Ko	5 55 3	+ 9	− 70	29	+ 22	± 9
	−3° 1256	5·68		− 3° 04′·7	− 2				± 8
945	Ross 414	...	...	6 4 37	+ 610	0	30	+ 29	± 12
	Ci. 20, 372	13·2		− 8° 56′·8	+ 609				± 8
946	P.G.C. 1574	5·68	F5	6 10 29	− 162	− 223	23	+ 13	± 7
	−0° 1234	6·10	...	− 0° 28′·5	− 175				± 4
767	Canopus (1)	−0·86	Fo	6 21 44	+ 15	+ 10	23	+ 26	± 5
	P.G.C. 1622	−0·58		−52° 38′·5	+ 4				± 2
	Canopus (2)	...	...	...	+ 15	+ 10	22	+ 31	± 5
					+ 4				± 2
	Mean							+ 28	± 4
770	Sirius (1)	−1·58	Ao	6 40 45	− 539	−1206	34	+396	± 8
	α Canis Majoris	−1·58		−16° 34′·7	− 575				± 4
	Sirius (2)	...	...	...	− 539	−1206	31	+378	± 8
					− 582				± 3
	Mean							+387	± 6
947	A.D.S. 5752	8·6	G5	6 59 21	...	...	32	+ 1	± 10
	−2° 1908	9·4		− 2° 54′·1	− 45				± 7
948	Z.C. 4346	8·7	Go	7 12 41	− 259	+ 223	26	+ 43	± 7
	−40° 3035	9·6		−40° 51′·5	− 242				± 6

No.	Name and D.M. No.	Mag. Vis. Ptg.	Spec. Type	R.A. Dec. (1900·0)	Unit 0″·001 Proper Motion R.A.	Proper Motion Dec.	P.E. Unit Weight	Parallax	P.E.
				h m s					
949	F.S. 3075	...	Ko	7 22 15	+ 179	+ 400	33	+ 22	± 9
	−51° 2481	10·7		−51° 08′·4	+ 177				± 9
950	F.S. 3383	...	K2	7 42 43	+ 108	− 195	26	+ 15	± 8
	−42° 3510	11·0		−42° 27′·2	+ 113				± 7
951	Z.C. 5375	6·9	Ko	8 04 21	− 159	+ 196	28	+ 22	± 8
	−48° 3495	8·0		−48° 06′·1	− 152				± 8
952	ϵ Hydræ	3·48	F8	8 41 29	− 191	− 54	27	− 4	± 9
	P.G.C. 2354	3·98		+ 6° 47′·1	− 199				± 7
953	G.C. 12468	7·87	Ko	8 56 12	− 141	− 50	28	+ 28	± 9
	−1° 2181	8·87		− 2° 10′·0	− 139				± 7
954	α Hydræ	2·16	K2	9 22 40	− 15	+ 30	27	+ 41	± 8
	P.G.C. 2533	3·23		− 8° 13′·5	+ 8				± 6
955	ι Hydræ	4·10	Ko	9 34 45	+ 46	− 69	23	+ 12	± 8
	P.G.C. 2595	5·10		− 0° 41′·3	+ 53				± 8
956	C.P.D. −76° 606	8·4	K5	9 55 28	...	...	38	+ 6	± 13
		9·6		−76° 48′·8	− 12				± 8
957	Ci. 20, 570	...	...	10 11 50	− 180	+ 400	28	+ 32	± 10
	−67° 1245	11·5		−67° 40′·0	− 295				± 7
958	−84° 262	...	...	10 14 00	...	...	25	+ 54	± 9
		10·8		−84° 37′·6	+ 5				± 6
959	−84° 263	8·5	G5	10 14 26	− 570	+ 340	28	+ 22	± 9
		9·3		−84° 35′·6	− 592				± 6
960	F.S. 8191	...	...	10 39 18	+ 177	− 129	20	+ 17	± 6
	−50° 5374	12·1		−50° 43′·5	+ 146				± 6
961	−17° 3336	...	M	11 10 19	...	...	19	+ 58	± 6
		11·2		−17° 34′·7	+ 174				± 4
	−17° 3337	...	M	11 10 21	+ 500	− 800	17	+ 56	± 5
	Ci. 20, 621	11·2		−17° 34′·7	+ 177				± 3
	Mean				...	...	...	+ 57	± 5
					+ 176				± 3
962	G.C. 16513	8·4	G5	12 00 9	− 517	+ 52	32	+ 17	± 10
	−0° 2532	9·2		− 0° 57′·2	− 489				± 6

No.	Name and D.M. No.	Mag. Vis. Ptg.	Spec. Type	R.A. Dec. (1900·0)	Unit 0″·001 Proper Motion R.A.	Proper Motion Dec.	P.E. Unit Weight.	Parallax	P.E.
				h m s					
963	G.C. 16674	7·36	Go	12 07 25	− 604	+ 401	29	+ 62	± 10
	−2° 3481	7·92		− 2° 32′·4	− 587				± 6
964	F.S. 10128	...	...	12 30 32	− 111	− 704	25	+ 95	± 8
	C.A.Z. −45° 332	13·4		−45° 22′·1	− 73				± 7
965	γ Virginis	3·65	Fo	12 36 36	− 567	+ 5	29	+129	± 10
	P.G.C. 3307	3·93		− 0° 54′·1	− 592				± 8
		3·68	Fo	...	...	...	36	+119	± 12
		3·96		...	− 591				± 10
	Mean				...	...	...	+125	± 8
					− 592				± 7
966	Ci. 20, 775	8·6	F5	13 16 06	− 807	+ 20	20	+ 6	± 7
	−38° 8457	9·3		−38° 47′·1	− 753				± 5
967	G.C. 18279	Var.	F5	13 24 33	− 334	− 117	24	+ 31	± 8
	S Chamæleontis	...		−77° 02′·9	− 375				± 9
968	G.C. 19326	7·6	Ko	14 14 25	− 659	− 144	28	+ 60	± 9
	−4° 3665	8·6		− 4° 41′·3	− 598				± 8
969	Z.C. 12598	7·9	Ko	14 38 27	− 684	− 381	17	+ 29	± 5
	−49° 9033	9·1		−49° 28′·9	− 629				± 5
970	υ Libræ	3·78	K2	15 30 57	− 8	− 6	18	+ 27	± 5
	P.G.C. 3962	4·85		−27° 48′·2	− 63				± 6
971	G.C. 21480	7·68	G5	15 53 21	− 142	− 119	36	+ 42	± 9
	−45° 10373	8·1		−45° 09′·8	− 205				± 10
972	Ci. 20, 962	7·87	G5	15 59 20	− 357	− 237	30	+ 44	± 8
	−32° 11405	8·4		−32° 35′·0	− 319				± 7
973	P.G.C. 4222	5·87	Ko	16 31 06	+ 450	− 319	27	+122	± 8
	12 Ophiuchi	6·87		− 2° 6′·7	+ 463				± 6
974	Wolf 629	...	M	16 50 05	− 800	− 877	32	+160	± 9
		14		− 8° 8′·3	− 821				± 7
975	Ci. 20, 1020	7·4	G5	17 01 10	+ 50	+ 580	22	+119	± 6
	−60° 6718	8·7		−60° 36′·9	+ 72				± 7
976	F.S. 16879	...	K5	17 27 35	+ 51	+ 465	31	+ 80	± 8
	−48° 11837	11·5		−48° 37′·4	+ 46				± 6

No.	Name and D.M. No.	Mag. Vis. Ptg.	Spec. Type	R.A. Dec. (1900·0)	Unit 0″·001 Proper Motion R.A.	Proper Motion Dec.	P.E. Unit Weight	Parallax	P.E.
				h m s					
977	Z.C. 16450	...	...	17 29 45	− 37	− 221	32	+ 68	± 12
	−49° 11579*p*	11·1		−49° 20′·3	0				± 14
	Z.C. 16451	10·1	G5	17 29 45	− 29	− 216	18	+ 32	± 5
	−49° 11579*f*	9·5		−49° 20′·4	− 11				± 6
	Mean				− 33	− 218	...	+ 37	± 5
					− 9				± 6
978	Z.C. 16678	8·4	G5	17 39 16	− 33	− 200	32	+ 19	± 9
	−40° 11815	8·8		−40° 41′·0	− 21				± 11
979	Σ 2208 B	...	...	17 41 15	...	...	23	+ 14	± 6
	−4° 4349	...		− 4° 26′·4	+ 7				± 7
	Σ 2208 A	9·3	Go	...	...	...	24	+ 9	± 7
		9·9		...	+ 12				± 8
	Mean							+ 12	± 5
980	G.C. 24990	7·7	G5	18 12 46	+ 22	− 152	24	+ 26	± 7
	−45° 12402	8·3		−45° 57′·5	+ 25				± 8
981	Z.C. 17611	9·1	Go	18 35 44	+ 139	− 237	21	+ 22	± 5
	−46° 12562	9·2		−45° 59′·4	+ 137				± 7
982	Z.C. 17613	9·2	Go	18 35 56	− 70	− 179	17	+ 50	± 5
	−50° 12100	9·2		−50° 15′·4	− 75				± 6
983	Z.C. 17687	8·9	Go	18 40 45	− 19	− 199	16	+ 51	± 4
	−50° 12149	8·9		−50° 48′·3	− 16				± 5
984	U.O.C. 53	...	...	19 06 38	+ 70	− 300	32	+ 40	± 9
	−66° 3416	11·5		−66° 55′·3	+ 20				± 10
413	F.S. 18616	9·9	F8	19 16 30	− 77	− 818	26	+ 3	± 6
	−45° 13178	10·2		−45° 15′·1	− 74				± 1
985	G.C. 27729	7·64	Go	19 55 30	− 304	− 364	29	+ 54	± 8
	−12° 5613	8·20		−12° 31′·2	− 311				± 6
986	U.O.C. 53	...	...	20 09 55	0	− 310	16	+ 27	± 4
		11·5		−67° 10′·6	0				± 4
987	P.G.C. 5294	4·51	Ko	20 33 10	+ 10	− 20	24	+ 5	± 7
	71 Aquilæ	5·51		− 1° 27′·3	+ 15				± 8
988	F. S. 19438	...	Ko	21 10 17	+ 273	− 201	20	+ 32	± 6
	−46° 13893	11·3		−46° 28′·4	+ 253				± 7

No.	Name and D.M. No.	Mag. Vis. Ptg.	Spec. Type	R.A. Dec. (1900·0)	Unit 0″·001 Proper Motion R.A.	Proper Motion Dec.	P.E. Unit Weight.	Parallax	P.E.
				h m s					
989	Ci. 20, 1274	...	...	21 11 37	− 510	+ 120	17	+ 66	± 6
		13·0		−68° 04′·3	− 471				± 5
990	s.f. above star	...	...	21 11 39	...	...	21	+ 22	± 7
		13·2		−68° 05′·5	+ 34				± 6
991	F.S. 19551	10	G5	21 27 31	+ 331	− 38	21	− 15	± 7
	−41° 14564	11·7		−41° 06′·2	+ 319				± 6
992	Co.D. −41° 14565	9·7	...	21 27 36	...	...	24	− 12	± 8
	C.P.D. −41° 9652	11·2		−41° 05′·6	− 38				± 7
993	γ Capricorni	3·80	F0*p*	21 34 33	+ 185	− 21	24	+ 24	± 7
	P.G.C. 5562	4·08		−17° 06′·8	+ 163				± 8
994	F.S. 19680	...	K5	21 46 04	+ 304	− 216	18	+ 35	± 5
	C.P.D. −52° 11948	11·7		−51° 55′·0	+ 291				± 6
995	F.S. 19718	...	M0	21 51 07	− 45	− 375	26	+ 65	± 7
	C.A.Z. −51° 83	12·1		−51° 28′·3	− 67				± 8
996	F.S. 19788	...	K7	22 01 39	+ 366	− 147	23	+ 44	± 7
	C.A.Z. −51° 30	11·1		−51° 42′·1	+ 309				± 9
997	F.S. 20561	...	...	22 13 09	+ 550	− 110	30	+ 24	± 9
	−42° 15867	13·0		−41° 53′·9	+ 553				± 8
998	θ Gruis	4·35	F5	23 01 15	− 44	− 23	25	+ 29	± 8
	P.G.C. 5949	4·77		−44° 3′·6	− 41				± 8
999	F.S. 20524	...	...	23 52 32	+ 371	− 186	23	+ 12	± 7
	C.A.Z. −47° 54	12·0		−46° 22′·0	+ 354				± 8
1000	Ci. 20, 1463	...	...	23 52 33	...	...	21	− 20	± 7
	−46° 14816	11·0		−46° 20′·9	+ 26				± 8

OBSERVATIONS OF OCCULTATIONS AT SYDNEY OBSERVATORY DURING 1938

(Communicated by the Government Astronomer)

The following observations of occultations were made and reduced in duplicate by H. W. Wood (H. W.) and E. E. Adderley (E. A.). The observations were made with a six-inch equatorial telescope, using a tapping key to record the times on the chronograph, no correction for personal effect being allowed in reading off. The reductions were made by Comrie's method, the lunation number being taken from the *Nautical Almanac*. The observational material is given in Table I and the results of the reductions in Table II. In each case the phase observed was disappearance at the dark limb.

TABLE I

No.	Date 1938	Star	Mag.	U.T.	Observer
				h m s	
1	June 6	B.D. −3° 3213	7·1	11 02 32·4	E. A.
2	,, 11	β^1 Scorpii	2·9	7 53 39·7	H. W.
3	,, 11	B.D. −19° 4308	5·1	7 53 54·9	H. W.
4	July 1	B.D. +8° 2289	6·7	9 39 48·2	E. A.
5	,, 5	B.D. −10° 3655	6·8	8 12 48·4	E. A.
6	Aug. 31	28 Libræ	6·2	8 43 39·1	H. W.
7	Sept. 2	B.D. −20° 4627	6·2	8 14 14·9	H. W.
8	Oct. 3	B.D. −15° 5564	6·8	8 29 35·5	H. W.
9	Dec. 1	B.D. +1° 4731	7·1	11 35 45·0	H .W.

TABLE II

No.	Lunation	p	q	p^2	pq	q^2	$\Delta\sigma$	$p\Delta\sigma$	$q\Delta\sigma$
1	191	+92	−40	84	−37	16	0·0	0·0	0·0
2	191	+98	+18	97	+18	3	−1·2	−1·2	−0·2
3	191	+98	+20	96	+20	4	−1·4	−1·4	−0·3
4	192	+52	+85	27	+44	73	−0·6	−0·3	−0·5
5	192	+94	−35	88	−33	12	−1·2	−1·1	+0·4
6	194	+99	−12	99	−12	1	−2·4	−2·4	+0·3
7	194	+97	−23	95	−22	5	−0·7	−0·7	+0·2
8	195	+82	−57	68	−47	32	−0·8	−0·7	+0·5
9	197	+93	+36	87	+34	13	−2·1	−2·0	−0·8